



# Parthenium Hysterophorus: Unveiling Harmful Impacts, Beneficial Potentials, and Novel Management Approaches

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## KEYWORDS

*Parthenium hysterophorus*, Nutrient-rich fertilizer, Waste management, Environmental impacts.

## ABSTRACT:

*Parthenium hysterophorus*, an invasive weed species known for its aggressive competitive nature and allelopathic properties, presents significant risks to various facets of human and environmental well-being. Despite its notorious reputation, recent clinical studies suggest potential avenues for harnessing its bioactive compounds for medicinal, agricultural, and environmental applications. These include exploration into its antidiabetic, antioxidant, antitumor, herbicidal, pesticidal, and antimalarial properties, hinting at a promising yet untapped resource. Moreover, *Parthenium* exhibits versatility as a nutrient-rich fertilizer, accessible and cost-effective for agricultural practices. Beyond its potential in medicine and agriculture, *Parthenium* offers solutions in waste management and pollution control. Its utility extends to herbicidal and insecticidal purposes, as well as its role as a phyto-remedial agent for extracting pollutants from agricultural residues. However, managing its invasive spread presents a formidable challenge, necessitating a multifaceted approach encompassing mechanical, chemical, cultural, and biological control methods. Furthermore, the intricate allelopathic interactions of *Parthenium* underscore both its complexity and potential. While its allelochemicals can suppress weed growth, they also engender both beneficial and detrimental interactions with other species, complicating regulation efforts. Understanding the mode of action of its toxic phenolic compounds is crucial in elucidating its mechanisms of weed suppression and exploring novel applications. This abstract provides an overview of *Parthenium*'s morphology, reproductive biology, environmental impacts, and management strategies, shedding light on its multifaceted nature and potential for diverse applications in agriculture, medicine, and environmental stewardship.

## 1.0 Introduction

*Parthenium (Parthenium hysterophorus L.)* is a weed that produces many seeds and has spread widely throughout Asia and other areas beyond its native range in Central and South America and the southern USA. Post-1955, *Parthenium* has become a major problem as a weed in agro habitats in over 30 nations [1]. *P. hysterophorus* infests a variety of landscapes, including farmsteads, fallow ground, orchards, and railway tracks. *Parthenium* weed is a member of the Asteraceae family, a large and diversified species with a worldwide distribution. Due to its many features, such as its short life cycle of 90–120 days, adaptability to photo-thermal conditions, a lack of natural enemies (usually), and rapid

growth, ability to spread via waterways and roadways, it is able to spread very quickly.

It is suspected that *Parthenium* was spread by vehicles or as a contaminant of seed lots in many cases. The spread of its seeds depends on water supply, livestock, and machinery movement. It has other common names, such as Santa Maria feverfew; bitter weed, which refers to the herbal flowering plant; and (sometimes) carrot grass. It is a fast-maturing annual weed and with a deep taproot and an erect stem that becomes woody with age. Due to its allelopathic influence, this weed is thought to cause allergic respiratory problems, mutagenicity in humans and livestock, and severe reductions in crop production[2]. According to Bajwa et al.[3], this toxic, aggressive species is one of the worst weeds worldwide.



This weed is responsible for multi-million-dollar losses in Australia and is considered a harmful crop in more than 45 countries[4], [5]. This plant is not only harmful to agriculture but also is a major factor in multiple human diseases. Among these are asthma, cancer, allergies, and stomach diseases. On the other hand, its potential benefits have been identified by various researchers. It is used as an antioxidant, an anticancer agent, and an antitumor agent, and its extracts are often used as pesticides to control diseases [6]. It is often used as an organic fertilizer because the proportions of N, Mg, Ca, K, and other nutrients are high in this plant, so it provides value to plant growth [7]. Parthenium improves seed germination, seedling growth, biomass, and yield indices for certain crops. Parthenin, hysterin, hymenin, and ambrosin comprise important compounds found in Parthenium plants.

Some of the most significant chemical compounds in Parthenium plants exhibit allelopathic activity. Allelopathy is a mechanism through which phytochemicals are produced by one plant, which increases or decreases the germination rate of another plant[8]. Allelopathy describes the beneficial or harmful effects of one plant on another plant, e.g., crop and weed species interact allelopathically. Allelopathy is caused by the release of biochemicals known as allelochemicals from plant parts through leaching, root exudation, volatilization, residue decomposition, and other processes in both natural and agricultural systems [9]. Allelopathic plants emit chemical compounds into the soil from their roots, and as nearby plants absorb these chemicals, they are inhibited or even destroyed. While an allelopathic effect is generally considered to be harmful, there may also be some beneficial effects, depending on the allelochemical target and other factors[10]. Allelochemicals produce cytotoxicity through physiological effects. Allelochemicals cause a variety of physiological effects, such as water absorption, leaf area expansion, and mineral nutrient absorption, which all decrease plant growth. Various allelochemicals were shown to reduce the absorption of indole-3-acetic acid (IAA) oxidase and other important macronutrients and micronutrients in germinating mustard seedlings by inhibiting root dry weight and root moisture content [11].

The first major objective of this study is to provide background information on the Parthenium weed, including its characteristics, harmful as well as beneficial

effects. Our second major objective is to review the effects it has on human health and explore its potential applications in fields related to Biotechnology.

## 1.1 Botanical Description

*P. hysterophorus* is an annual herbaceous plant that reproduces mostly through seeds. Following sprouting, the young plant has a basal rosette of bright green and finely lobed leaves that measure about 8–20 cm in length and 4–8 cm in breadth. During unfavourable conditions, the rosette stage can continue to grow up to a maximum of 2.5 m long. Both leaves and stems have short and fluffy hair or trichomes, four styles of which have been recognized and considered for their taxonomic significance. The flower heads are terminal and somewhat hairy; they consist of several small white capitula-shaped florets. Usually, each head has five productive ray florets, although occasionally six or eight. Thousands of branches, which develop in separate clusters, produce compressed black seeds about 2 mm in size. Originally, Parthenium was found in the Gulf of Mexico, the USA, the West Indies, and Central America. Parthenium has now invaded many other countries and regions. Both Parthenium's life cycle and how it spreads.[12]

## 2.0 Harmful Effects

### 2.1 Effect on Soil

With allelopathic plants present, there are strong correlations between crop development and soil microorganisms. Direct integration of Parthenium residues into soil has the potential to have allelopathic impacts on crop development and establishment[13]. As a result of *P. hysterophorus* expansion, native and non-native species have been hampered or replaced. Soil nitrogen and organic content were found to be considerably higher in infested plots than in non-invaded plots. The invaded plots had the highest levels of pH, phosphorus, and potassium; the non-invaded plots had low to moderate levels[14]. Parthenium weed can take nutrients even from nutrient-depleted soils, resulting in high tissue levels of nitrogen (3%), phosphorus (2%), potassium (4%), and other macronutrients and micronutrients, making it an excellent green manure for field crops. According to Dogra and Shood [15], allelochemicals are formed by *P. hysterophorus* leaves and discharged into the soil by leaching or



decomposition, and they affect plant growth directly or indirectly by affecting the soil's physio-chemical characteristics.

## 2.2 Effect on Crops

Several scholars have noted that *Parthenium* can have positive or negative effects on various crops. In East Africa, sorghum grain production was reduced by 40–97% if *Parthenium* was allowed to grow unchecked for the entire season. *Parthenium*, on the other hand, had an allelopathic impact on the sprouting and the development of other crops. Germination period, growth rate, and yield reductions of Indian traditional crops resulted from soils being infected by the *Parthenium* weeds because the leaves contain p-coumaric acid and caffeic acid. These are responsible for growth inhibition. Seedling growth of *Zea mays* was seriously disturbed in another study, and crucifers' seedling elongation was affected by *Parthenium* leaf extracts. *P. hysterophorus* has an influence on bean growth at low concentrations, and *Parthenium* ash concentration levels can boost seed germination, radicle length, and biomass production. When *P. hysterophorus* residues are combined in soil, they have a negative impact on the germination and subsequent seedling growth of native plants. In a number of dicot and monocot plants, parthenin has been described as a germination and radical growth inhibitor. The allelopathic characteristics of *Parthenium* make it difficult for agricultural crops such as wheat, rice, maize, pigeon pea, sorghum, and black gram to germinate and flourish, and their yields may decrease by as much as 40%. [16]

## 2.3 Effect on Livestock

*Parthenium* growing in grasslands can be virtually invisible, making it more likely that livestock will consume it, especially if grassland managers fail to manage it. *Parthenium* decreases livestock productivity by reducing the amount of forage. It may also affect grazing animals' welfare, milk production, and meat quality. *P. hysterophorus*-fed buffalo and hybrid calves develop atrophic eruptions, alopecia, skin depigmentation, and anemia. In mature livestock, continuous feeding of *P. hysterophorus* for up to 12 weeks can cause anorexia and dermatitis (*Osmanabadi*) [17]. When cattle consume *Parthenium* or they come into contact with the weed on a regular basis, poisoning may result. Death, rashes on the body and

udders, alopecia, loss of skin pigmentation, allergic skin reactions, dermatitis, diarrhea, anorexia, and pruritus are all possible outcomes for those animals. The psychological behavior of animals can also be influenced by *Parthenium* [18]. *Parthenium* silage has nutritional value that is fairly similar to that of a sheep's normal dietary requirements, and the seeds of *Parthenium* obtained from the silage did not germinate [19].

## 2.4 Effect on Human Health

*Parthenium* roots can cause allergic diseases, such as photodermatitis, asthma, hay fever, skin rashes, excessive water loss, peeling skin, swelling, and itching of the mouth and nose [20]. Some of the main elements contained in *Parthenium* are chlorogenic acid, anisic acid, p-anisic acid, caffeic acid, and benzoic acids, which are very harmful to humans and livestock. Hand weeding in *Parthenium*-infested fields can cause skin diseases, and *Parthenium*-related allergies can also cause malarial infection-related fever. Skin infections, allergies, eczema, fever, allergic rhinitis, dark spots, burning, and swelling around the eyes are all signs of long-term exposure to this herb. Diarrhea, extreme papular erythematous eruptions, and shortness of breath are all symptoms of *P. hysterophorus* [16]. Respiratory symptoms normally start with increased fever and respiratory problems and become more severe after 3–5 years of incremental exposure, resulting in asthma and allergic bronchitis.

## 3.0 Beneficial Effects

### 3.1 Antidiabetic Effects

*P. hysterophorus* aqueous extract showed strong hypoglycemic action. Within 2 h, fasting blood glucose levels in alloxan-induced diabetic rats dropped significantly ( $p < 0.01$ ) [17]. As a result, this treatment may be helpful, mainly for type II diabetics who are insulin-independent [21], [22]. Fever, neurological conditions, diarrhea, urine infections, malaria, and emmenagogue have all been treated with distilled *P. hysterophorus* liquor in traditional medicine, and women's vaginal and urinary disorders have sometimes been treated using tea produced from the leaves and roots of *P. hysterophorus* [23]. In addition, some tribal people use it to treat itching, skin conditions, rheumatic pain, eczema, heart complications, and reproductive problems.



### 3.2 Antioxidant Activity

Due to their carcinogenic effects, free radicals are considered to be contributors to certain diseases. Synthetic antioxidants are regarded as contributing factors [24]. That is why natural antioxidants have drawn scientists' interest. When compared to Stevia's (*Stevia rebaudiana* Bertoni) effect, the methanolic extracts of *P. hysterophorus* demonstrated significant antioxidant activity [7]. As a result, this plant could be a suitable natural antioxidant source. A new, potent natural antioxidant could be made commercially available after investigating *Parthenium* for its active antioxidant ingredient(s) [17].

### 3.3 Antitumor Activity

Alberto Ramos [25] showed that *P. hysterophorus* extracts have antitumor potential through *in vitro* activity, with promising results in terms of tumor size reduction. The levels of neoplastic indicators, such as glutathione, cytochrome P-450, glutathione transferase, and UDP-glucuronyl transferase, were significantly altered, which slowed tumor growth and enhanced survival [17]. *P. hysterophorus* aqueous extract had hypoglycemic activity in alloxan-induced treated patients [21].

### 3.4 Antimicrobial Activity

Medically, *Parthenium* is known chiefly for its anticancer properties, but it may also be used for hepatic amoebiasis [26]. It has antibacterial, antifungal, and antiviral properties against *P. aeruginosa*, *E. coli*, and *Candida albicans*, respectively [27].

### 3.5 Larvicidal Effect

*P. hysterophorus* root and stem extracts are effective against mosquito larvae, particularly *Aedes aegypti* [28]. Chemical components extracted from leaves have significant effects on both the lifespan and the production of adult *Lipaphis erysimi* [29]. A new depolarizing neuromuscular junctional block was observed on rats if *Parthenium* leaf extract was used as an alternative to anticholinesterase agents, such as neostigmine [30].

### 3.6 Parthenium Compost

*P. hysterophorus* is high in micronutrients and macronutrients, such as N, P, K, Ca, Mg, and chlorophyll, making it ideal for composting [31]. The plant's early

growth, development, and dry matter output are all hampered by its high phenolic content. Hence, the composting of *Parthenium* and *Eichhornia crassipes* (a water weed rich in polyphenol oxidases) causes considerable reductions in phenol content, organic carbon content, and C/N and C/P ratios. Combining *Parthenium* and water hyacinth in compost provides a weed-control solution and a path to sustainable organic farming [17]. However, its phytotoxicity prevents plants from growing quickly and reduces dry matter harvests. Vermicomposting of *Parthenium* consumes nutrients and restricts unwanted plant noxiousness [32]. Furthermore, it also improves nutrient quality, which could be beneficial for organic farming and bioremediation [33].

### 3.7 Herbicidal Effects

Researchers have been focusing on plant-derived chemicals as eco-friendly herbicide alternatives for weed management for the past several decades. *P. hysterophorus* extracts reduced weed density significantly and also had allelopathic effects on *Eragrostis tef*, *Cynodon dactylon*, *Cyperus rotundus*, *Digitaria sanguinalis*, *Portulaca oleracea*, *Echinochloa crus-galli*, *Euphorbia prostrata*, *Xanthium strumarium*, etc. [17], [34]. By suppressing cell division mediated by gibberellin and indole acetic acid, the sesquiterpene lactone is assumed to be responsible for its allelopathic influence on adjacent plants [31]. It was also reported that ash concentrations above 3% reduced germination, seedling growth, development of plumule, and radicle length and biomass. There is substantial evidence that *Parthenium* extract could be used as a possible herbicide, given its effects on weed germination, density, and biomass. Hence, environmentally friendly, natural herbicides based on *Parthenium* could be derived as alternatives to synthetic herbicides [35].

### 3.8 Pesticidal Effects

The efficacy of *Parthenium* as an inoculum source was tested. *P. hysterophorus* is a serious pasture-invading weed that reduces pasture production 90% of the time. It suppresses the growth of other plants in grasslands and pastures, thereby reducing fodder supplies [36].

### 3.9 Industrial Effluent Removal

The degradation of the environment caused by heavy metals has become a global issue. Nickel (II) and cadmium (Cd) are used in silver factories, electroplating,



zinc-based manufacturing, and Cd/Ni battery industries. Parthenium has shown the ability to absorb both nickel and methylene blue dye from wastewater and industrial waste. However, the highly toxic metals it absorbs can cause kidney disease, elevated blood pressure, bone deformity, and red blood cell (RBC) destruction. Ni and Cd can cause cancer and other diseases. Parthenium is a safe, affordable, and environmentally friendly absorbent of such industrial waste[16], [17].

### 3.10 Effective as a Nano Biofertilizer

Parthenium-based nano biofertilizers offer a promising solution to enhance soil fertility and crop productivity while minimizing environmental impacts. Through innovative nanotechnology approaches, the plant's bioactive compounds can be encapsulated or engineered into nanostructures to ensure efficient nutrient delivery and uptake by plants. These nano biofertilizers have the potential to improve nutrient use efficiency, reduce fertilizer requirements, and mitigate soil degradation. Moreover, by harnessing Parthenium's invasive nature, this approach could contribute to its management while simultaneously providing a valuable resource for agricultural sustainability. Research in this field holds promise for addressing the dual challenge of enhancing food security and environmental conservation in a rapidly changing world.

### 3.11 Other Economic Benefits

The capacity of *P. hysterophorus* to generate enzymes such as xylanase has been investigated [15], [37]. Parthenium is very effective at removing dyes, dissolved heavy metals, and other contaminants, such as phenolics, from the atmosphere. It has benefited the imaging, mechanical, electronic, drug delivery, and molecular diagnosis industries greatly[15]. Nanotechnology has emerged as a remarkable tool for addressing a variety of challenges in everyday life. It has proved extremely advantageous to the imaging, mechanical, electronic, medication delivery, and molecular diagnosis industries. Researchers' interest in the synthesis of NPs from *P. hysterophorus*, such as TiO<sub>2</sub>, AgNPs, and zinc oxide nanoparticles, has risen recently[38], [39]. These nanoparticles can be antifungal, antibacterial, environmentally safe, and effective at preventing vector-borne diseases. Furthermore, when combined with manure, Parthenium has been used very effectively to produce biogas and in treating heavy metal pollutants through bioremediation. Researchers have also found that nitrogen, calcium, magnesium, and potassium are present in high proportions in this plant. Hence, the application of organic manure produced with Parthenium could play a great role in production enhancement.

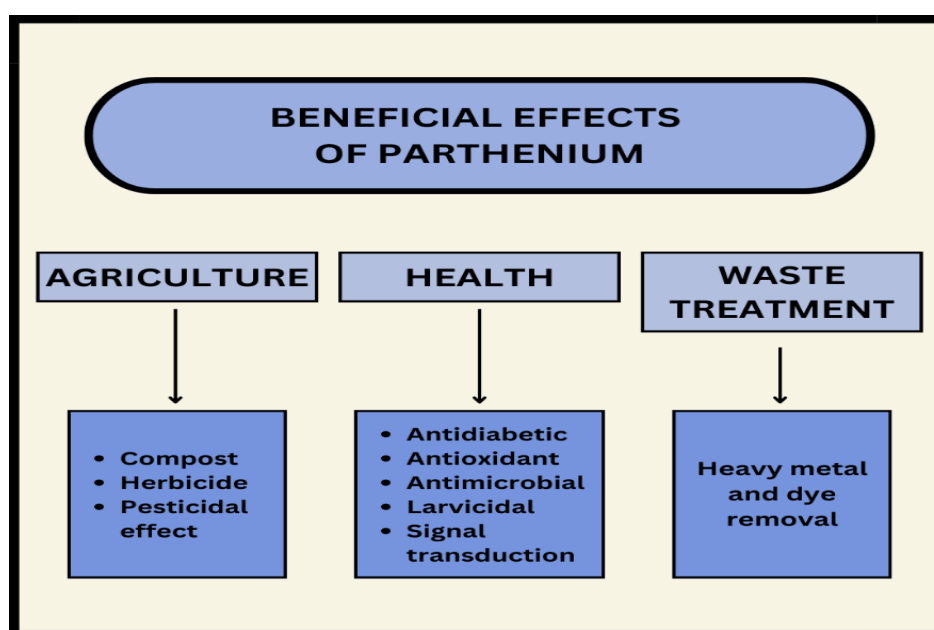


Figure-1: Beneficial Effects of Parthenium



## 4.0 Management

### 4.1 Use of Allelopathic Plants

Parthenium, in general, is a poisonous, pernicious, hazardous, allergenic, and aggressive weed that is a major hazard to humans, crops, and cattle. The use of plants with allelopathic effects is a promising means to control Parthenium. Two approaches are generally taken, i.e., (1) maintaining natural biodiversity and (2) selecting plants in target areas through planting. The second approach involves the intentional manipulation of natural enemies to control harmful weeds, and there are some natural enemies of Parthenium, which may be employed, such as *Cassia sericea*, *Cassia tora*, *Cassia auriculata*, and *Mirabilis jalapa*.

### 4.2 Physical Control

Hand hoeing before flowering and harvesting is the most cost-effective method of minimizing Parthenium. However, this method can cause health problems, such as allergic reactions. Some landowners have had success plowing the Parthenium weed when it is still in the tassel stage, which should be followed by sowing seed or planting the field. Hand weeding is a time-consuming and challenging method. Burning is another strategy for managing Parthenium, but it requires a large amount of fuel[18], [40].

### 4.3 Biocontrol Agents

Biocontrol techniques to reduce Parthenium constitute environmentally responsible and economically viable methods of control. The leaf rust fungus, *Puccinia xanthii* Schwein. var. *parthenii-hysterophorae*, and a stem-boring weevil, *Listronotus setosipennis* (Hustache), were found to be potential biocontrol agents for this weed[41]. Two biocontrol agents have been reported to have some effect in Ethiopia: the stem-galling moth and the seed-feeding weevil. The stem-galling moth *Epiblema strenuana* reduced weed density, plant height, and flower production by 90%, 40%, and 82%, respectively. Furthermore, insects such as *Listronotus setosipennis* (stem-boring weevil), *Bucculatrix parthenica* (leaf-mining moth), and *Smicronyx lutulentus* (seed-feeding weevil) have demonstrated usefulness in Parthenium control[42]. After employing biocontrol measures since the mid-1990s, the infested region in Central Queensland has decreased[36]. The

insects caused a large decline of Parthenium in confined areas, and the insects mainly feed on the weed's leaves, which ultimately damages the weed's ability to regenerate. Seeds and roots, on the other hand, maintain their normal biomass and are the primary drivers of the Parthenium's life cycle. The radicle and hypocotyl lengths of Parthenium seedlings exposed to cultural filtrates of *Fusarium oxysporum*, *Drechslera australiensis*, *Fusarium solani*, and *Drechslera hawaiiensis* were significantly reduced[33]. Great efforts have been made to regulate populations of Parthenium via various biocontrol agents, such as microbial pathogens, insects, and botanicals, over the last three to four decades. The use of plant pathogens is an environmentally friendly solution that can be used in agro-ecosystems [43]. Spore suspension of *Cladosporium* sp. (MCPL 461) with 3% sucrose showed a 70%–80% germination reduction (*Lantana camara* and *Chromolaena odorata* were also tested)[44].

### 4.4 Use of Synthetic Herbicides

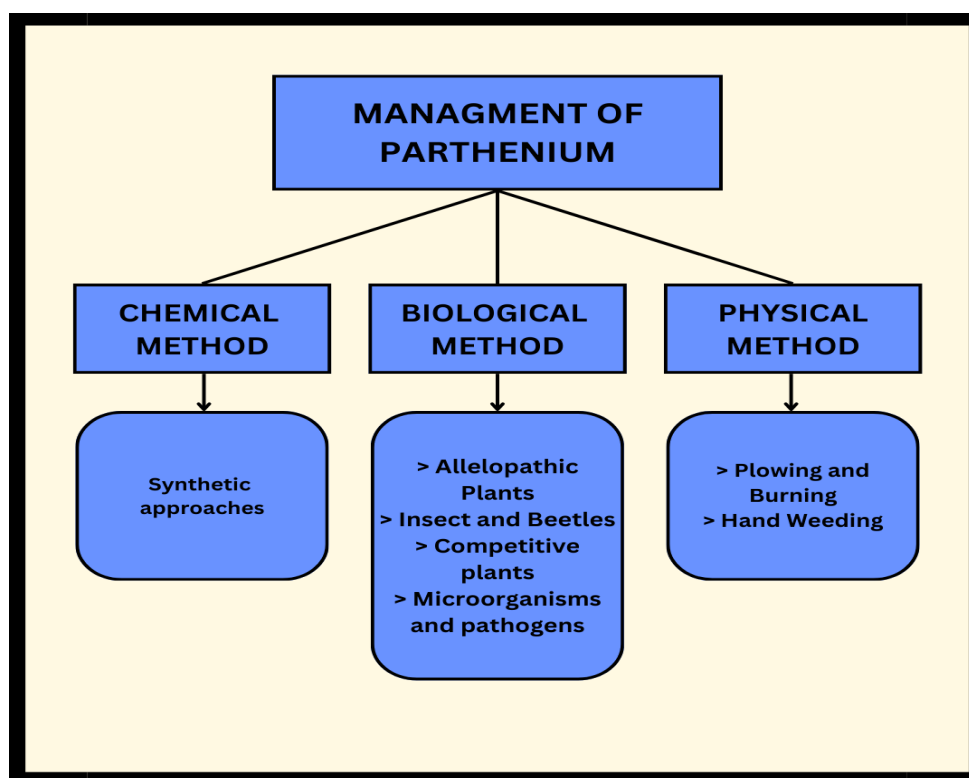
In locations where Parthenium's natural enemies are absent, chemical control is an effective technique of control. Glyphosate is a herbicide used the world over to control Parthenium[45]. Glyphosate offered greater than 93% control of Parthenium at the rosette stage, according to Javaid [46]. Javaid [46]also demonstrated that glyphosate, glufosinate, and trifloxysulfuron reduced the presence of Parthenium weeds by 86–95% at the bolted stage. Singh et al.[47]found that 2,4-D, atrazine, metribuzin, metsulfuron, chlorimuron, and glufosinate failed to suppress Parthenium at 18 WAT; however, glyphosate at 2.7 and 5.4 kg ha<sup>-1</sup> provided greater than 95% control of bolted plants. The combination of pendimethalin, bispyribac-sodium, and bensulfuron-methyl afforded excellent control of Parthenium (about 90%)[48]. Similarly, Parthenium plants can be killed by glyphosate and isoproturon [46], [49]. Pre-emergence herbicides such as metolachlor plus atrazine, pendimethalin, and cyanazine plus atrazine have been shown to reduce the weed density of Parthenium[50]. Kaur et al. [51]observed that 15 days after spraying, and application of both 2,4-D EE (0.2%) and metribuzin (0.25% and 0.50%) was effective at controlling Parthenium: total eradication of the Parthenium population was achieved, and weed emergence was prevented.



#### 4.5 Controlling by Use

One of the most effective means of controlling this hazardous vegetation is management by use. There are numerous applications for Parthenium as a raw material

or as an addition, some of which relate to herbicides, pesticides, insecticides, ethanol production, composting, green manure, nanoparticle synthesis, silkworm feed additives, and decolorizing agents [18]



**Figure-2:** Management of Parthenium

#### 5.0 Chemical Constituents, Allelopathic Composites And Phytochemistry

Allelochemicals produced by *P. hysterophorus* and some of the physiological effects are explained by F. Einhellig, 2003 [11]. Allelochemicals have a range of physiological effects, including reduction in plant growth, excessive water absorption, leaf area expansion, and mineral nutrient absorption. The mechanism of any phytotoxic mix involves making the cell membrane permeable in general; ion flux and hydraulic conductivity are thereby disrupted. The changes to the membrane can have an impact on the plant–water relationship, photosynthesis rate, oxygenation, ion equilibrium, and stomata opening and closing. In the lettuce plant, the relative water content and leaf water content can be reduced by 10%. This is caused by a reduction in CO<sub>2</sub> supply to mesophyll cells and a reduction in photosynthesis. Gulzar and Siddiqui[52]reported that p-coumaric acid, ferulic acid,

salicylic acid, and caffeic acids produce water stress in treated seedlings of *Glycine max* and *Sorghum bicolour*. Also, several allelochemicals reduced radicle dry weight and moisture content in sprouting mustard seedlings. Caffeine's impact on cell division is limited because it inhibits cell membrane growth and the synthesis of nucleic acid chains. The phenolic acids p-hydroxy phenylacetic acid, p-coumaric acid, and ferulic acid can affect the photosynthesis of plants[53].

A large number of allelochemicals can be separated from Parthenium plants to produce new compounds. Parthenium is a potent allelopathic crop; P-hydroxybenzoic acid and phenolic compounds being the important allelochemicals in its plants, and these allelochemicals are used for weed control[54]. The toxin's major components are "Parthenin" and other phytotoxic compounds, for example, caffeic acid, vanillic acid, anisic acid, chlorogenic acid, ferulic acid,



fumaric acid, coumaric acid, quercelagetin, and hydroxybenzoic acid [16]. Much available research also highlights its effect on agriculture and natural habitats regarding health risks.

It was found that, Parthenium's chemistry is currently extensively understood. The elements of *P. hysterophorus* vary depending on their chemotype and geographical distribution of seeds. Plants that produce large amounts of bioactive compounds and medicinal plants can have in their leaves and flowers more than 45 sesquiterpene lactones]. *P. hysterophorus* has 23 chemicals that account for 90.1% or more of the volatile oils [55]. Phytochemicals are also categorized as either primary or secondary components, based on their roles in biological processes. Sugars, amino acids, vitamins, nucleic acid purines and pyrimidines, chlorophylls, and other primary constituents are among them. The remaining plant compounds, such as alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumins, saponins, phenolics, and glucosides, are considered secondary compounds[56], [57]. Rahmat et al. [7] have been investigating the mineral composition of *P. hysterophorus* and showed that significant amounts of potassium, calcium, magnesium, sodium, iron, zinc, copper, molybdenum, lead, lithium, nickel, cadmium, chromium, and manganese are present in Parthenium plants. Parthenin, hymenin, coronopilin, dihydroisoparthenin, hysterin, hysterophorin, and tetraeurin-A were found in the sesquiterpene lactones of *P. hysterophorus* from various geographical zones [16].

The phenolic acids isolated from *P. hysterophorus* plant parts extracted in different organic solvents includes: caffeic acid ( $C_9H_8O_4$ ), p-coumaric acid ( $C_9H_8O_3$ ), p-anisic acid ( $C_8H_8O_3$ ), ferulic acid ( $C_4H_4O_4$ ), fumaric acid ( $C_4H_4O_4$ ), p-hydroxy benzoic acid ( $C_7H_6O_3$ ), chlorogenic acid ( $C_{16}H_{18}O_9$ ), neochlorogenic acid ( $C_{16}H_{18}O_9$ ), protocatechuic acid ( $C_7H_6O_4$ ), aerulic acid, and vanillic acid ( $C_4H_4O_4$ ) [25]. Among flavonoids, quercetagetin-3,7-dimethyl ether, apigenin, kaempferol-3-o-glucoside, quercetin-3-o-glucoside, kaempferol-3-o-glucuarabinoside, luteolin, lignin, jaceidin, syringaresinol, santin, chrysoeriol, kaempferolglucoside, centaureidin, 6-hydroxykaempferol-3,6-dimethylether, tanetin (6-hydroxykaempferol-3,6,4-trimethylether), quercetinglucoside, 6-hydroxykempferol-3,7-dimethylether and kaempferol-glucoarabinoside can be

found [58]. The major allergen in *P. hysterophorus* pollen was identified by Gupta et al. [59] as a new hydroxyproline-rich glycoprotein. Das et al. [60] identified four acetylated pseudoguaianolides, as well as several other recognized compounds, from the flowers of *P. hysterophorus*. Venkataiah et al. [61] isolated a new sesquiterpenoid, charminarone, the first seco-pseudoguaianolide, from the complete plant, along with numerous other recognized chemicals. From the chloroform extract of this weed, Chhabra et al. [62] found three ambrosanolides.

The extract of different parts of Parthenium plant contains various pseudoguaianolide as: parthenin, anhydroparthenin, 2,3-dihydro-10 $\alpha$ -hydroxyparthenin, 8 $\beta$ -hydroxyparthenin, ambrosin, 10 $\alpha$ -hydroxyparthenin, tetraeurin-A, tetraeurin-E, hymenin, 15-deacetyltetraeurin-A, damsine, 2 $\beta$ -hydroxycoronopilin, 8 $\beta$ -hydroxycoronopilin, hysterin, scopoletin, conchasin-A, 3 $\beta$ -acetoxynoeambrosine, ambrosanolides, 8- $\beta$ -acetoxysterone-C, deacetyltetraeurin-A, hysteron A-E, 8- $\beta$ -acetoxysterone-C, dihydroxyparthenin, acetylated pseudoguaianolide, coronopilin, 13-hydroxyparthenin, charminarone, dihydroisoparthenin, 13-methoxydihydroparthenin, balchanin, costunolide, 2 $\beta$ ,13 $\alpha$ -methoxydihydroparthenin, epoxyartemorin, 8- $\alpha$ -hydroxystaiaatin, 11,13-dihydroparthenin, 13-methoxy-11,13-dihydroambrosin, 3- $\beta$ -hydroxycostunolide, 5- $\beta$ -hydroxyreynosin 13-methoxydihydroambrosin, 1- $\beta$ -hydroxyarbusculin, and 13-methoxy-11,13-dihydroparthenin [63], [64].

## 6.0 Conclusion

In conclusion, Parthenium hysterophorus emerges as a complex and multifaceted botanical entity, characterized by its harmful impacts on ecosystems and human health, as well as its untapped potential for beneficial applications. While its invasive nature and allelopathic properties pose significant challenges to agriculture, environmental sustainability, and public health, recent research highlights promising avenues for leveraging its bioactive compounds in medicinal, agricultural, and remedial contexts. The exploration of Parthenium's antidiabetic, antioxidant, antitumor, and pesticidal properties, alongside its potential as a nutrient-rich fertilizer and phyto-remedial agent, underscores its value beyond its status as a noxious weed.



However, effective management of Parthenium requires a nuanced understanding of its biology, allelopathic interactions, and control measures. Integrating mechanical, chemical, cultural, and biological approaches is imperative to mitigate its spread and minimize its ecological and economic impacts. Moreover, continued research into the mode of action of its allelochemicals and phenolic compounds holds promise for developing innovative management strategies and unlocking novel applications.

In essence, this review underscores the need for a balanced perspective on Parthenium hysterophorus, recognizing both its harmful consequences and its potential contributions to agriculture, medicine, and environmental stewardship. By unveiling its harmful impacts, beneficial potentials, and novel management approaches, we can strive towards harnessing the full spectrum of Parthenium's capabilities while mitigating its adverse effects on ecosystems and human well-being.

## References

- [1] S. Adkins and A. Shabbir, "Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.)," *Pest Manag Sci*, vol. 70, no. 7, pp. 1023–1029, Jul. 2014, doi: 10.1002/ps.3708.
- [2] Mtenga and Neema, "Developing an eco-friendly and bio-management strategy against parthenium hysterophorus (L.) in Arusha, Tanzania," Nelson Mandela African Institution of Science and Technology, Arusha, 2019. doi: 10.58694/20.500.12479/248.
- [3] A. A. Bajwa, G. Mahajan, and B. S. Chauhan, "Nonconventional Weed Management Strategies for Modern Agriculture," *Weed Sci*, vol. 63, no. 4, pp. 723–747, Dec. 2015, doi: 10.1614/WS-D-15-00064.1.
- [4] A. Shabbir, A. A. Bajwa, K. Dhilepan, M. Zalucki, N. Khan, and S. Adkins, "Integrated use of biological approaches provides effective control of parthenium weed," *Arch Agron Soil Sci*, vol. 64, no. 13, pp. 1861–1878, Nov. 2018, doi: 10.1080/03650340.2018.1464150.
- [5] R. Kaur, T. K. Das, T. Banerjee, R. Raj, R. Singh, and S. Sen, "Impacts of sequential herbicides and residue mulching on weeds and productivity and profitability of vegetable pea in North-western Indo-Gangetic Plains," *Sci Hortic*, vol. 270, p. 109456, Aug. 2020, doi: 10.1016/j.scienta.2020.109456.
- [6] S. Patel, "Harmful and beneficial aspects of Parthenium hysterophorus: an update," *3 Biotech*, vol. 1, no. 1, pp. 1–9, Jul. 2011, doi: 10.1007/s13205-011-0007-7.
- [7] A. Khan, "Nutritional investigation and biological activities of Parthenium hysterophorus," *Afr J Pharm Pharmacol*, vol. 5, no. 18, pp. 2073–2078, Nov. 2011, doi: 10.5897/AJPP11.497.
- [8] D. J. Sturm, C. Kunz, and R. Gerhards, "Inhibitory effects of cover crop mulch on germination and growth of *Stellaria media* (L.) Vill., *Chenopodium album* L. and *Matricaria chamomilla* L.," *Crop Protection*, vol. 90, pp. 125–131, Dec. 2016, doi: 10.1016/j.cropro.2016.08.032.
- [9] J. J. Ferguson, B. Rathinasabapathi, and C. A. Chase, "Allelopathy: How Plants Suppress Other Plants," *EDIS*, vol. 2013, no. 3, Mar. 2013, doi: 10.32473/edis-hs186-2013.
- [10] S. Latif, G. Chiapusio, and L. A. Weston, "Allelopathy and the Role of Allelochemicals in Plant Defence," 2017, pp. 19–54. doi: 10.1016/bs.abr.2016.12.001.
- [11] F. Einhellig, "Mode of Allelochemical Action of Phenolic Compounds," in *Allelopathy*, CRC Press, 2003, pp. 217–238. doi: 10.1201/9780203492789.ch11.
- [12] H. M. K. Bashir *et al.*, "A Mystic Weed, Parthenium hysterophorus: Threats, Potentials and Management," *Agronomy*, vol. 11, no. 8, p. 1514, Jul. 2021, doi: 10.3390/agronomy11081514.
- [13] H. P. SINGH, D. R. BATISH, J. K. PANDHER, and R. K. KOHLI, "Phytotoxic effects of *Parthenium hysterophorus* residues on three *Brassica* species," *Weed Biol Manag*, vol. 5, no. 3, pp. 105–109, Sep. 2005, doi: 10.1111/j.1445-6664.2005.00172.x.
- [14] B. Timsina, B. B. Shrestha, M. B. Rokaya, and Z. Münzbergová, "Impact of Parthenium hysterophorus L. invasion on plant species composition and soil properties of grassland communities in Nepal," *Flora - Morphology, Distribution, Functional Ecology of Plants*, vol. 206, no. 3, pp. 233–240, Mar. 2011, doi: 10.1016/j.flora.2010.09.004.
- [15] Kuldeep S. Dogra, "Phytotoxicity of Parthenium hysterophorus residues towards growth of three



- native plant species (*Acacia catechu* Willd., *Achyranthes aspera* L. and *Cassia tora* L.) in Himachal Pradesh, India,” *International Journal of Plant Physiology and Biochemistry*, vol. 4, no. 5, Apr. 2012, doi: 10.5897/IJPPB11.009.
- [16] S. Patel, “Harmful and beneficial aspects of *Parthenium hysterophorus*: an update,” *3 Biotech*, vol. 1, no. 1, pp. 1–9, Jul. 2011, doi: 10.1007/s13205-011-0007-7.
- [17] T. P. Khaket, H. Aggarwal, D. Jodha, S. Dhanda, and J. Singh, “*Parthenium hysterophorus* in Current Scenario: A Toxic Weed with Industrial, Agricultural and Medicinal Applications,” *Journal of Plant Sciences*, vol. 10, no. 2, pp. 42–53, Feb. 2015, doi: 10.3923/jps.2015.42.53.
- [18] T. Tafese Bezuneh, “Phytochemistry and Antimicrobial Activity of *Parthenium hysterophorus* L.: A Review,” *Science Journal of Analytical Chemistry*, vol. 3, no. 3, p. 30, 2015, doi: 10.11648/j.sjac.20150303.11.
- [19] T. R. Narasimhan, B. S. Keshava Murthy, N. Harindranath, and P. V. Subba Rao, “Characterization of a toxin from *Parthenium hysterophorus* and its mode of excretion in animals,” *J Biosci*, vol. 6, no. 5, pp. 729–738, Dec. 1984, doi: 10.1007/BF02702716.
- [20] “Allelopathic Effect of Aqueous Extracts of *Parthenium (Parthenium Hysterophorus L.)* Parts on Seed Germination and Seedling Growth of Maize (*Zea Mays L.*),” *Journal of Agriculture and Crops*, no. 12, Dec. 2018, doi: 10.32861/jac.412.157.163.
- [21] V. Patel, V. Chitra, Pl. Prasanna, and V. Krishnaraju, “Hypoglycemic effect of aqueous extract of *Parthenium hysterophorus* L. in normal and alloxan induced diabetic rats,” *Indian J Pharmacol*, vol. 40, no. 4, p. 183, 2008, doi: 10.4103/0253-7613.43167.
- [22] A. Kar, B. K. Choudhary, and N. G. Bandyopadhyay, “Preliminary studies on the inorganic constituents of some indigenous hypoglycaemic herbs on oral glucose tolerance test,” *J Ethnopharmacol*, vol. 64, no. 2, pp. 179–184, Feb. 1999, doi: 10.1016/S0378-8741(98)00118-4.
- [23] A. Gurib-Fakim, M. D. Sewraj, J. Gueho, and E. Dulloo, “Medicinal Plants of Rodrigues,” *International Journal of Pharmacognosy*, vol. 34, no. 1, pp. 2–14, Jan. 1996, doi: 10.1076/phbi.34.1.2.13177.
- [24] B. N. Ames, M. K. Shigenaga, and T. M. Hagen, “Oxidants, antioxidants, and the degenerative diseases of aging,” *Proceedings of the National Academy of Sciences*, vol. 90, no. 17, pp. 7915–7922, Sep. 1993, doi: 10.1073/pnas.90.17.7915.
- [25] A. Ramos, R. Rivero, A. Visozo, J. Piloto, and A. García, “Parthenin, a sesquiterpene lactone of *Parthenium hysterophorus* L. is a high toxicity clastogen,” *Mutation Research/Genetic Toxicology and Environmental Mutagenesis*, vol. 514, no. 1–2, pp. 19–27, Feb. 2002, doi: 10.1016/S1383-5718(01)00321-7.
- [26] B. Venkataiah, C. Ramesh, N. Ravindranath, and B. Das, “Charminarone, a seco-pseudoguaianolide from *Parthenium hysterophorus*,” *Phytochemistry*, vol. 63, no. 4, pp. 383–386, Jun. 2003, doi: 10.1016/S0031-9422(03)00147-X.
- [27] T. S. Talakal, S. K. Dwivedi, and S. R. Sharma, “In vitro and in vivo therapeutic activity of *Parthenium hysterophorus* against *Trypanosoma evansi*,” *Indian J Exp Biol*, vol. 33, no. 11, pp. 894–6, Nov. 1995.
- [28] S. Kumar *et al.*, “Impact of *Parthenium hysterophorus* leaf extracts on the fecundity, fertility and behavioural response of *Aedes aegypti* L.,” *Parasitol Res*, vol. 108, no. 4, pp. 853–859, Apr. 2011, doi: 10.1007/s00436-010-2126-1.
- [29] S. K. Sohal, P. J. Rup, H. Kaur, N. Kumari, and J. Kaur, “Evaluation of the pesticidal potential of the congress grass, *Parthenium hysterophorus* Linn. on the mustard aphid, *Lipaphis erysimi* (Kalt.),” *J Environ Biol*, vol. 23, no. 1, pp. 15–8, Jan. 2002.
- [30] P. Vijayalakshmi, K. M. Vijayalakshmi, and N. V. Nanda Kumar, “Depolarizing neuromuscular junctional blocking action of *Parthenium hysterophorus* leaf extracts in rat,” *Phytotherapy Research*, vol. 13, no. 5, pp. 367–370, Aug. 1999, doi: 10.1002/(SICI)1099-1573(199908/09)13:5<367::AID-PTR434>3.0.CO;2-3.
- [31] P. Kishor, A. K. Ghosh, S. Singh, and B. R. Maurya, “Potential use of *Parthenium (Parthenium hysterophorus L.)* in Agriculture,” *Asian Journal of Agricultural Research*, vol. 4, no. 4, pp. 220–225, Jun. 2010, doi: 10.3923/ajar.2010.220.225.
- [32] A. Yadav and V. K. Garg, “Recycling of organic wastes by employing *Eisenia fetida*,” *Bioresour*



- Technol*, vol. 102, no. 3, pp. 2874–2880, Feb. 2011, doi: 10.1016/j.biortech.2010.10.083.
- [33] T. P. Khaket, M. Singh, S. Dhanda, T. Singh, and J. Singh, “Biochemical characterization of consortium compost of toxic weeds *Parthenium hysterophorus* and *Eichhornia crassipe*,” *Bioresour Technol*, vol. 123, pp. 360–365, Nov. 2012, doi: 10.1016/j.biortech.2012.07.107.
- [34] L. NIGATU, A. HASSEN, J. SHARMA, and S. W. ADKINS, “Impact of *Parthenium hysterophorus* on grazing land communities in north-eastern Ethiopia,” *Weed Biol Manag*, vol. 10, no. 3, pp. 143–152, Sep. 2010, doi: 10.1111/j.1445-6664.2010.00378.x.
- [35] Mst. Motmainna, A. S. Juraimi, Md. K. Uddin, N. B. Asib, A. K. M. M. Islam, and M. Hasan, “Bioherbicidal Properties of *Parthenium hysterophorus*, *Cleome ruidosperma* and *Borreria alata* Extracts on Selected Crop and Weed Species,” *Agronomy*, vol. 11, no. 4, p. 643, Mar. 2021, doi: 10.3390/agronomy11040643.
- [36] K. Dhileepan, “Biological Control of *Parthenium (Parthenium hysterophorus)* in Australian Rangeland Translates to Improved Grass Production,” *Weed Sci*, vol. 55, no. 5, pp. 497–501, Oct. 2007, doi: 10.1614/WS-07-045.1.
- [37] P. Nargotra, V. Sharma, and B. K. Bajaj, “Consolidated bioprocessing of surfactant-assisted ionic liquid-pretreated *Parthenium hysterophorus* L. biomass for bioethanol production,” *Bioresour Technol*, vol. 289, p. 121611, Oct. 2019, doi: 10.1016/j.biortech.2019.121611.
- [38] K. Thandapani *et al.*, “Enhanced larvicidal, antibacterial, and photocatalytic efficacy of TiO<sub>2</sub> nanohybrids green synthesized using the aqueous leaf extract of *Parthenium hysterophorus*,” *Environmental Science and Pollution Research*, vol. 25, no. 11, pp. 10328–10339, Apr. 2018, doi: 10.1007/s11356-017-9177-0.
- [39] M. F. Anwar, D. Yadav, S. Kapoor, J. Chander, and Mohd. Samim, “Comparison of antibacterial activity of Ag nanoparticles synthesized from leaf extract of *Parthenium hystrophorus* L in aqueous media and Gentamicin sulphate: *in-vitro*,” *Drug Dev Ind Pharm*, vol. 41, no. 1, pp. 43–50, Jan. 2015, doi: 10.3109/03639045.2013.845840.
- [40] V. B. Kushwaha and S. Maurya, “Biological utilities of *Parthenium hysterophorus*,” *Journal of Applied and Natural Science*, vol. 4, no. 1, pp. 137–143, Jun. 2012, doi: 10.31018/jans.v4i1.238.
- [41] W. Mersie *et al.*, “Host range evaluation of the leaf-feeding beetle, *Zygogramma bicolorata* and the stem-boring weevil, *Listronotus setosipennis* demonstrates their suitability for biological control of the invasive weed, *Parthenium hysterophorus* in Ethiopia,” *Biocontrol Sci Technol*, vol. 29, no. 3, pp. 239–251, Mar. 2019, doi: 10.1080/09583157.2018.1545220.
- [42] A. Shabbir, K. Dhileepan, C. O’Donnell, and S. W. Adkins, “Complementing biological control with plant suppression: Implications for improved management of parthenium weed (*Parthenium hysterophorus* L.),” *Biological Control*, vol. 64, no. 3, pp. 270–275, Mar. 2013, doi: 10.1016/j.biocontrol.2012.11.014.
- [43] W. El-Sayed, “Biological control of weeds with pathogens: Current status and future trends / Biologische Schadpflanzbekämpfung mit Pathogenen: Aktueller Status und Trends von morgen,” 2005. [Online]. Available: <https://www.jstor.org/stable/45154904>
- [44] Kumar Anuj, Verma V.C., Gond S.K., Kumar v., and Kharwar R.N., Bio-control potential of *Cladosporium* sp.(MCPL-461), against a noxious weed *Parthenium hysterophorus*. 2009. Accessed: Apr. 22, 2024. [Online].
- [45] L. Orcaray, A. Zulet, A. Zabalza, and M. Royuela, “Impairment of carbon metabolism induced by the herbicide glyphosate,” *J Plant Physiol*, vol. 169, no. 1, pp. 27–33, Jan. 2012, doi: 10.1016/j.jplph.2011.08.009.
- [46] A. Javaid, “Efficacy of some common herbicides against *Parthenium* weed,” 2007. [Online]. Available: <https://www.researchgate.net/publication/258210859>
- [47] S. Singh, A. Yadav, R. S. Balyan, R. K. Malik, and M. Singh, “Control of Ragweed *Parthenium (Parthenium hysterophorus)* and Associated Weeds,” *Weed Technology*, vol. 18, no. 3, pp. 658–664, Sep. 2004, doi: 10.1614/WT-03-128R2.
- [48] A. A. Bajwa, A. Ullah, M. Farooq, B. S. Chauhan, and S. Adkins, “Chemical control of parthenium



- weed (*Parthenium hysterophorus* L.) in two contrasting cultivars of rice under direct-seeded conditions,” *Crop Protection*, vol. 117, pp. 26–36, Mar. 2019, doi: 10.1016/j.cropro.2018.11.009.
- [49] A. Shabbir, “CHEMICAL CONTROL OF *Parthenium hysterophorus* L.,” 2014. [Online]. Available: <https://www.researchgate.net/publication/265340349>
- [50] H. Khan, K. B. Marwat, M. Azim, K. Khyber, and S. Hashim, “Herbicidal control of parthenium weed in maize,” 2014. [Online]. Available: <https://www.researchgate.net/publication/287540547>
- [51] M. Kaur, N. K. Aggarwal, V. Kumar, and R. Dhiman, “Effects and Management of *Parthenium hysterophorus*: A Weed of Global Significance,” *Int Sch Res Notices*, vol. 2014, pp. 1–12, Aug. 2014, doi: 10.1155/2014/368647.
- [52] R. R. Barkosky and F. A. Einhellig, “Effects of salicylic acid on plant-water relationships,” *J Chem Ecol*, vol. 19, no. 2, pp. 237–247, Feb. 1993, doi: 10.1007/BF00993692.
- [53] D. Abhilasha, N. Quintana, J. Vivanco, and J. Joshi, “Do allelopathic compounds in invasive *Solidago canadensis* s.l. restrain the native European flora?,” *Journal of Ecology*, vol. 96, no. 5, pp. 993–1001, Sep. 2008, doi: 10.1111/j.1365-2745.2008.01413.x.
- [54] K. Jabran, “Manipulation of Allelopathic Crops for Weed Control; Springer: Cham, Switzerland,” *Springer (ISBN 978-3-319-53185-4)*, 2017, Accessed: May 14, 2024. [Online]. Available: <https://link.springer.com/book/10.1007/978-3-319-53186-1>
- [55] A. Pareek, M. Suthar, G. Rathore, and V. Bansal, “Feverfew (*Tanacetum parthenium* L.): A systematic review,” *Pharmacogn Rev*, vol. 5, no. 9, p. 103, 2011, doi: 10.4103/0973-7847.79105.
- [56] M. S. Thesis and S. Ayele, “THE IMPACT OF PARTHENIUM (*PARTHENIUM HYSTEROPHORUS* L.) ON THE RANGE ECOSYSTEM DYNAMICS OF THE JIJIGA RANGELAND, ETHIOPIA,” 2007.
- [57] R. R. Barkosky, F. A. Einhellig, and J. L. Butler, “Caffeic Acid-Induced Changes in Plant–Water Relationships and Photosynthesis in Leafy Spurge *Euphorbia esula*,” *J Chem Ecol*, vol. 26, no. 9, pp. 2095–2109, 2000, doi: 10.1023/A:1005564315131.
- [58] M. N. Abbas, M. Mahmood-Ul-Hassan, and N. Rana, “Phytochemical constituents of weeds: baseline study in mixed crop zone agroecosystem,” 2013. [Online]. Available: <https://www.researchgate.net/publication/255993824>
- [59] N. Gupta, B. M. Martin, D. D. Metcalfe, and P. V. S. Rao, “Identification of a novel hydroxyproline-rich glycoprotein as the major allergen in *Parthenium pollen*,” *Journal of Allergy and Clinical Immunology*, vol. 98, no. 5, pp. 903–912, Nov. 1996, doi: 10.1016/S0091-6749(96)80006-6.
- [60] B. Das, N. Salvanna, R. A. Kumar, and R. Das, “Our Phytochemical Research on *Parthenium hysterophorus*,” *Mini Rev Org Chem*, vol. 17, no. 7, pp. 843–854, Oct. 2020, doi: 10.2174/1570193X17666191218092812.
- [61] B. Dutt Yashwant Singh Parmar *et al.*, “Phyto-Chemistry of Congress grass (*Parthenium hysterophorus* L.) and Harmful and Beneficial effect on Human and Animals: A review,” *Int J Chem Stud*, vol. 5, no. 4, pp. 643–647, 2017, [Online]. Available: <https://www.researchgate.net/publication/327955372>
- [62] A. Sahrawat, J. Sharma, S. N. Rahul, S. Tiwari, and D. V. Rai, “*Parthenium hysterophorus* Current Status and Its Possible Effects on Mammalians- A Review,” *Int J Curr Microbiol Appl Sci*, vol. 7, no. 11, pp. 3548–3557, Nov. 2018, doi: 10.20546/ijemas.2018.711.407.
- [63] B. Das *et al.*, “Pseudoguaianolides from the Flowers of *Parthenium hysterophorus*,” *Helv Chim Acta*, vol. 89, no. 2, pp. 285–290, Feb. 2006, doi: 10.1002/hlca.200690032.
- [64] B. Das, P. Jangili, M. Srilatha, J. Kashanna, and R. Das, “Pseudoguaianolides from a collection of the flowers of *Parthenium hysterophorus* Linn. (Compositae) †,” 2013. [Online]. Available: <http://signpostejournals.com>