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PARTHENIUM HYSTEROPHORUS L: A REVIEW OF ITS PHYTOCHEMICAL, BIOLOGICAL AND THERAPEUTICAL APPLICATIONS

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ABSTRACT: *Parthenium hysterophorus L, also known as false ragweed or wild carrot, is a flowering plant belonging to the Asteraceae family. It is a weed that causes many losses to ecosystem due to its ability to spread in to the agricultural and causes allergic reactions into humans and animals. This plant has many medicinal, antibacterial, antifungal, anticancerous, anti-tumor and anti-allergic activities and many folks are using it. Control measures include chemical, physical, and biological methods. The purpose of this review is to provide a comprehensive overview of the plant's origin, life cycle, geographic distribution, phytochemistry, pseudo-guaianolides, flavonoids, phenolic acids, minerals, clinical applications, synthetic applications, economic importance, and control methods. This comprehensive review highlights the diverse medicinal value of P. hysterophorus and provides direction for future investigations into leveraging this plant for modern medicine.*

Keyword: *Parthenium hysterophorus*, anti-inflammatory, anti-microbial, anti-parasitic, deadly invasive weed

INTRODUCTION

A dangerously invasive and highly deadly weed known as *Parthenium* is present in more than 30 countries (McConnachie et al., 2011). This plant poses a serious hazard to humans, animals, and agriculture (Kohli and Daizy, 1994). This invasive perennial herbaceous weed destroys ecosystems, invades remote areas, and can cause severe allergic reactions in animals. It also causes serious issues in forestry, crops, and rangelands. Many of the weed plant's biological and ecological variables contribute to its invasiveness (Navie et al., 1996). This plant severely affects crop productivity in the agricultural sector and negatively impacts farming, livestock, and human livelihoods (Patel, 2011). Several methods have been used to eradicate, manage, and control the plant's spread, including fire, synthetic weedkillers, the application of eucalyptus oil, and biotic regulation methods like sustaining the leaves to coleopteran. It has been furthermore demonstrated that parthenium species have numerous health advantages, including its uses as treatments for malaria, neuralgia, diarrhoea, and skin inflammation (Kumar et al., 2013) These plants also have commercial worth and are being used in industry (Parashar et al., 2009) such as removing metal, eliminating aquatic plants, producing biodiesel from cow manure, and creating biopesticides (Detta and Saxena, 2001). It is renowned for rapid growth and excellent fertility under all climatic circumstances, but notably in warmer one areas (Nguyen et al., 2017). This comprehensive review highlighted the medicinal value of *P. hysterophorus* and provides direction for future investigations into leveraging this plant for modern medicine.

1.1. Phytochemistry analysis of *P. hysterophorus*

The examination of the aerial components of *P. hysterophorus* for phytochemicals uncovered a variety of compounds, such as sesquiterpene lactones, pseudoguaianolides, flavonoids, phenolic acids, volatile oils, alkaloids, lipids, steroids, sterols, proteins, tannins, and metallic elements (Pandey, 2015). Moreover, the plant was found to have considerable quantities of the amino acids glycine and proline, with smaller amounts of other amino acids like alanine and lysine. Additionally, the plant contains two amino sugars, N-acetyl galactosamine and N-acetylglucosamine, in a ratio of 2:1 (Guyana and Paraguay, 2014).

1.1.1. Pseudoguaianolides of *P. hysterophorus*

Studies from Mexico, the West Indies, India, and the United States have revealed that parthenin is the main component of *P. hysterophorus*. Additionally, it was cut off from people in one Texas hamlet, southern Bolivia, and central Argentina (Shah, 2014). *P. hysterophorus* variants can be divided into "parthenin races" and "hymenin races" due to the distinct ancestries of parthenin and hymenin" The compound coronopilin has been further isolated from *P. hysterophorus* (Herz and Högenauer 1961). Hysterin and dihydroisoparthenin were also found in *P. hysterophorus* (Picman et al., 1983; Picmen et al., 1982; Vivar et al., 1966). There have also been reports of Deacetyltetraneurin, 11, 13-dihydro-4,4-dihydroxyneoambrosin, and 8-acetoxyhysterone (Pandey, 2015). The plant's blooms also included the following four acetylated pseudoguaianolides: 3'-acetoxy neoambrosin, 3'-acetoxy neoambrosin, and 4'- acetoxy-11', 13'-H-dihydroparthenin (Gupta, 1977; Sethi et al., 1987).

1.1.2. Flavonoids

The flavonoids santin, luteolin, apigenin, chrysoeriol, centaureidin, jaceidin, kaempferol and quercetin-3-O-glucoside were all isolated from *P. hysterophorus* (Bezuneh, 2015).

1.1.3. Phenolic acids

Phenolic acids, such as caffeic acid, chlorogenic acid, p-hydroxybenzoic acid, p-anisic acid, vanillic acid, salicylic acid, gentisic acid, proto-catechuic acid, and neochlor, are abundant in the roots *of P. hysterophorus* (Bezuneh 2015; Jung and Ahmad 2006). In addition, (Kaur et al. 2021) extracted 2,3(H)-2,3-epoxyambrosin and hydroxy-guaiene from the plant's roots. Furthermore, roots of *P. hysterophorus* contain 0.35 percent of histamine. Despite this information, no study has yet investigated the roots of this hazardous plant, indicating the need for further testing (Kushwah and Maurya 2012)

1.1.4. Minerals

According to phytochemical research, the leaves of *P. hysterophorus* are a rich source of various metallic elements. The minerals found in *P. hysterophorus* include calcium (74.14±0.43 g/g), sodium (12.37± 0.15), zinc (4.730±0.008), manganese (0.099±0.002), potassium (28.09±0.31), magnesium (7.161±0.41), iron (8.36±0.02), copper (0.097±0.003), lithium, and potassium (Rahmat et al., 2011). Inorganic components are known to help maintain natural glucose tolerance, and therefore, using *P. hysterophorus* as a replacement for green vegetables in different meal preparations may offer health benefits (Bezuneh, 2015).

1.2. Clinical studies of *P. hysterophorus*

1.2.1. Prevention and treatment of migraine

By releasing globules in blood platelets connected to the aetiology of migraines, *P. hysterophorus* can be utilized to cure hemicrania. A significant 12-week, double-blind, placebo-controlled trial found that certain migraine sufferers might be successfully treated with uncooked plant leaves. Another repeatable, double-blind, placebo-controlled trial found that giving a dose of 100 mg for 60 days significantly reduced the severity of migraines. According to further research, a capsule with a dosage of 70 to 114 mg can effectively treat migraines. The analyses above show that these treatments help avoid migraines; nevertheless, a practical strategy and clinical trials are needed to use *P. hysterophorus* effectively (Shan et al., 1976).

1.2.2. Rheumatoid arthritis

Previous studies have shown that *P. hysterophorus* can inhibit the release of globules from blood macrophages, which have been linked to the development of autoimmune and joints inflammatory diseases. In a six-month study, forty-one female patients diagnosed with rheumatoid arthritis were given dry feverfew (70-86 mg) or inactive drugs once a day (Patrick et al., 1989).

1.2.3. Anti-HIV activity

P. hysterophorus leaf extract has been tested for its antiviral efficacy against H.I.V. reverse transcriptase enzyme. The experiment tested the efficacy at two different dosages (0.6 and 6.0 g/ml) using an H.I.V. reverse transcriptase inhibitor kit. The extracts' low to moderate inhibitory power (50%) suggested that purification and more research would help identify the compound that inhibits reverse transcriptase activity (Kumar et al., 2013).

1.2.4. Tumour activity

Tumours are growths of aberrant tissue, either benign or malignant, that can enlarge a particular body region without often inflaming it. *P. hysterophorus* methanolic flower extract exhibits anti-cancer activity when given to rats with transplanted lymphocytic leukaemia (Mukherjee and Chatterjee, 1993).

1.2.5. Sleeping aid

The hormone melatonin, which governs the sleep-wake cycle in humans and other animals, is widely used to treat insomnia (Jung et al., 2006). Melatonin, a naturally occurring sleep aid used for generations, has recently been found in several plant cells and tissues. Indoleamine is widely recognized for changing and regulating circadian cycles (Ansari et al., 2010). This unintentionally fosters an environment suitable for potent antioxidant activity (Jung and Ahmad, 2006). *Parthenium* formulations made with alcohol included significant melatonin and may be used as a sleep aid. The potential for *Parthenium* plant extracts to be utilized as a sleep aid was discovered through HPLC and selective confirmation approaches like ELIZA (Ansari et al., 2010).

1.3. Biological activities of *P. hysterophorus*

Parthenium hysterophorus exhibits diverse biological activities such as anti-inflammatory, anti-fungal, anti-cancer and insecticidal effects (Pandey 2009; Roy and Shaik 2013). Parthenin, the active compound present in the plant, contains three unique components that have been associated with its various pharmacological effects (Dase et al., 2006; Khatak et al., 2016; Shah, 2014).

1.3.1. Anti-inflammatory activity of *P. hysterophorus*

Rats with carrageenan-induced paw edema responded to gastroenteric engrossment of *P. hysterophorus* retrieved at doses of about 11, 21, and 40 mg/kg body composition with anti-inflammatory effects. Furthermore, fresh leaf ethanolic preparations at a concentration of 200 mg/kg body weight significantly reduced inflammation in rats with carrageenan-induced paw edema by preventing the activity of cellular phospholipases (Roy and Shaik, 2013). The presence of exomethylene on the lactone molecule gives parthenin its anti-inflammatory properties. Additionally, 1.2 mg/kg of body weight of parthenolide therapy produced anti-inflammatory benefits.

1.3.2. Anti-microbial activity of *P. hysterophorus*

Plants contain natural substances such as tannins, phenolic compounds, flavonoids, and essential oils that make them effective antibacterial agents (Kumar et al., 2014). Research has shown that the non-substituted cyclopentenone parthenin moiety can inhibit the growth of *Rhizobium* and *Azotobacter*, two types of rhizosphere flora, without relying on the -methylene-lactone moiety (Lalita 2018). *P. hysterophorus* extracts have demonstrated antibacterial properties against various human ailments caused by gram-positive and gram-negative bacteria, such as *C. albicans*, *E. coli*, *B. subtilis*, *P. aeruginosa*, *K. pneumonia*, *S. cerevisiae*, and *Staphylococcus*, outperforming various standard controls, including azithromycin, cepaxim, amphotericin-B (Kaur et al., 2020). Water-soluble ash extract, with ofloxacin as a positive control, has been shown to be effective against *S. enterica* and *S. epidermis*. Additionally, several *P. hysterophorus* preparations have been effective against *Fusarium solani*, a fungal disease that causes Fusarium wilt, by acting as active agents against dermatophytes and other pathogenic fungi (Zunera et al., 2012). An aqueous extract of *P. hysterophorus* has also been found to prevent the growth of numerous fungi, including *P. chrysogenum*, *M. gypseum*, *A. niger*, and *F. oxysporu* (Kumar, 2014).

1.3.3-Antiparasitic activities of *P. hysterophorus*

The multi-drug resistant *Plasmodium falciparum* strain is successfully treated with parthenin and many of its replacements. The growth of the malarial parasite has been observed to be significantly decelerated by the hydroalcoholic extract obtained from *P. hysterophorus*, which is attributed to its diverse effects on both the host and *Plasmodium* membranes (Roy and Shaik 2013; Shah 2014). Moreover, studies conducted in vitro have demonstrated that a 50% alcoholic extract derived from *P. hysterophorus* possesses strong anti-*Trypanosoma evansi* properties. When given to rats with trypanosome illness intraperitoneally at a dose of 100–300 mg/kg body mass, the natural plant displayed anti-trypanosomal action (Kaur et al., 2020). To evaluate the anti-amoebic effects of parthenin, axenic and polygenic cultures associated with *Entamoeba histolytica* are employed in vitro (Meena et al., 2017). It has been discovered that a parthenin works in vitro similarly to metronidazole and is more effective than conventional therapy (Ravi, 2020). *Meloidogyne incognita* and *Helicotylendus dihystera* have both been shown to be susceptible to a *P. hysterophorus* extract's nematicidal effects (Kaur et al., 2020). Nematode formation is inhibited by up to 70% to 100% in three hours at 500 and 1000 ppm parthenin. A leaf extract mixed with soil also lessens the papaya root galling brought on by *M. incognita* (Hasan and Jain, 1984).

1.3.4. Anti-nociceptive activity of *P. hysterophorus*

Mice raised to writhe in reaction to acetic acid were given oral doses of *P.*

hysterophorus extract that displayed significant anti-nociceptive activity ranging from 10 to 40 mg/kg of body composition (Kaur et al., 2021). The hypo-glycaemic activity of aqueous *P. hysterophorus* extract (100 mg/kg body weight) consumption considerably decreased blood glucose levels in healthy and alloxan-induced diabetic rats, albeit the effect was less pronounced than that of glibenclamide (Ravi, 2020; Roy and Shaik 2013). Furthermore, mice that ingested fresh leaf extract exhibited a slight reduction in glucose levels (Khatak et al., 2015).

1.3.5. Thrombolytic activity of *P. hysterophorus*

Crude extract of methanol showed similar effects to the common thrombolytic drug streptokinase, which dissolves blood clots during heart attacks. *P. hysterophorus* showed intense thrombolytic action (Roy and Shaik, 2013).The thrombolytic activity of a 100 mL methanolic extract of *P. hysterophorus* was tested on blood samples from two volunteers in combination with the drug streptokinase. The results showed that the percentage of clot lysis was 16.52% and 2.91% for volunteer-1, and 19.52% and 4.02% for volunteer-2. This activity may also have an impact on preventing migraines by blocking the production of serotonin from platelets through agents such as collagen, adrenaline, adenosine diphosphate, and sodium arachidonate that cause platelet aggregation (Al-Mamon et al., 2011).

1.3.6. Analgesics uses of *P. hysterophorus*

A methanolic extract of *P. hysterophorus* demonstrates significant analgesic behaviour, much like pethidine, at dosages of 2.5 and 5 mg/kg body weight. Due to its effects on Swiss albino mice's central nervous system (Shikha and Jha, 2018).

1.3.7. Mutagenic activity of *P. hysterophorus*

The mutagenic potential of *P. hysterophorus* was discovered through studies employing Salmonella and the mouse bone marrow micronucleus test. When exposed to a crude extract of *P. hysterophorus*, Salmonella strain TA 98 mutated (Ramos et al., 2001). The outcomes were unsatisfactory when 0.19-1.22 moles of parthenin per plate were employed to treat a *Salmonella typhimurium* TA 102 strain. It was also demonstrated to be harmful at 7.62 moles per plate or higher concentrations. Additionally, mice blood cells exhibit chromosomal abnormalities following a 20-hour exposure to 10-60 M (Kaur et al., 2021).

1.3.8. Insecticidal properties of weed *P. hysterophorus*

Termites, cockroaches, migrating grasshoppers, and *Melanoplus sanguines* are just a few of the pests that may be controlled by parthenin (Picmen et al., 1982). *Spodoptera litura* larvae of the fifth instar, *Dysdercus angulatus*, are poisoned by plant extracts from *P. hysterophorus'* aerial parts. In addition, it has been shown that cowpea seeds, mites, infestations of the cabbage leaf beetle webber *Crocidolomia binotalis*, and the pulse beetle *Callosobruchus maculates*, and their offspring are all somewhat toxic (Joshi et al., 2016). Natural defences against termites, fungi, and molluscan borer assaults include resin from *P. hysterophorus*. The petroleum ether extract of aerial *P. hysterophorus* sections had a deleterious impact on the life duration and repeatability of the mustard aphid *Lipaphis merycism* (Patel, 2011).

1.4. Synthetic applications of *P. hysterophorus* extracts

In addition to the biological uses of *P. hysterophorus* and its main component, parthenin, that have been addressed, several parthenin derivatives are produced by chemical or pharmacological transformation (Dase et al., 2000). The methylene-lactone component of parthenin regulates the bioactivity of the substance. The compound's skeleton, made up of the cyclopentanone moiety, offers a significant opportunity for structural alterations that might enhance the compound's function by yielding appropriate derivatives (Shah et al., 2010; Weng et al., 2021). Pharmacological applications for various parthenin molecules vary (Dhillon and Battu, 1996). The multiple reactions and procedures that derivatize parthenin lead to synthesizing many analogues with medicinal applications (Reddy et al., 2011).

1.4.1. Green utilization for *P. hysterophorus*

One method of eliminating *P. hysterophorus* is to remove and burn crops infected with the weed in countries like India. To keep the weed under management and slow its growth, eco-friendly (green) management strategies must be created. Environmentally safe nanoparticles may be produced using *P. hysterophorus* (Parashar et al., 2009) that produced inorganic nanoparticles with uses in the electrical and medical industries. Artificial nanoparticles also reduce the spread of bacterial and fungal diseases (Saini et al., 2015). *P. hysterophorus* has an allelopathic tendency, which makes it suitable for use as green manure to improve soil fertility and the production of crops like wheat, rice, and maize (Javaid and Shah, 2010). Eragrostis, water hyacinth, and Salvinia cannot grow because of *P. hysterophorus'* allelopathic properties. It makes other weeds feel ashamed. *P. hysterophorus* can be used for vermicomposting since it contains a variety of macro- and micronutrients that can be composted with *Eudrilus eugeniae*, which in turn encourages the growth of worms (Saini et al., 2015).

1.4.2. Economic importance of *P. hysterophorus*

P. hysterophorus is widely used in the creation of biogas and charcoal. It is suggested to be a suitable substrate for biogas generation utilizing anaerobic digestion because of its ability to generate 60–70% of methane. Biogas generation may increase using cow manure (Gunaselan, 1988). *P. hysterophorus* may also be used to create biochar, a soil enhancer that boosts agricultural yields while also bringing down the price of artificial fertilizers (Shafiq, 2016). In addition to the uses listed above, Lignocellulose is abundant in *P. hysterophorus*, primarily used in manufacturing paper, textiles, pharmaceuticals, cosmetics, and packaging (Naithani et al., 2008). Additionally, it is utilized in producing oxalic acid (Maine et al., 1987), as well as a source of spices, food, and ingestible proteins for animal feed (Kushwah and Maurya, 2012; Tawers and Subbah Rao, 1993). The extract can also be utilized as a feed supplement for silkworms (Kaur et al., 2014). Although it hasn't yet reached its full potential, some studies indicate that parthenin waste may extract lignin and then utilize it to make the xylanase enzyme cheaply (Saini et al., 2017).

1.4.3. Role of *P. hysterophorus* as larvicide

Larvicides are substances that can be chemical or biological that act as insecticides, mainly when applied to an insect's larval stage. *P. hysterophorus* is excellent at killing larvae. Parthenium research has demonstrated that aphid management can benefit from the plant's larvicidal properties, which are detrimental to crops, humans, and numerous mosquito larvae. It has been discovered that parthenium extracts have a significant larvicidal effect against *Aedes aegypti* larvae and other larvae (Kumar et al., 2011). The lifespan and capacity for the reproduction of *Lipaphis erysimi* were significantly decreased in this weed's leaf extract. Modern chemical pesticides and insecticides harm plants and people who regularly ingest them. *Parthenium* is a suitable biological source for larvicidal treatments due to its biological substitutability (Detta and Saxana 2001).

1.4.4. *P. hysterophorus* role in compost mechanism

P. hysterophorus is widely known for providing high-quality micro- and macromolecule sources and working well as compost in agricultural settings (Rahmat et al., 2011). These macro- and micronutrients can produce plants more healthily because they are plentiful in plants. However, this plant's high phenolic and oil level raises the possibility that it may adversely influence the development, maturation, and procreation of agricultural plants. Therefore, the plant may be recycled or degraded and subsequently utilized as a crop nutrition source rather than being consumed directly. This demonstrates a practical effect on *Eichhornia crassipes* and can be used as compost and biofertilizer. Studies show that *Parthenium* and Eichhornia synergistically affect nutritional value and Parthenium toxicity (Khatak et al., 2015).

Table 1: Different impacts of *P. hysterophorus* biodiversity and environment.

Categories	Mechanism of action	Impacts	Impacts
Human's	Toxic features of monocytes.	Itchy rashes, pulmonary infections, dermatitis, allergic rhinitis, asthma, erythema, and allergies	(Gnanevel and Naterajan, 2014; Matenga et al., 2020); (Pandey, 2009; Sahrawat et al., 2018)
Vegetation	It impacts the ecosystems naturally and results in the loss of much native florae.	Habitat devastation, endophyte effects, hazards to flora and fauna, and biodiversity decline	(Chib et al., 2013; Hooper et al., 1990)
Crops or fields	Release of environmentally harmful phytotoxic compounds	Low agricultural production destroys grain samples and reduces the carrying capacity of pastures.	(Picmen et al., 1983)
Wild animals/ livestock	The immune system is weakened as a result of a reduction in the number of white blood cells	Species in the wild or livestock. The immune system declines as white blood cells fall beyond normal levels. Anorexia nervosa, prurigo, mouth sores, dermatitis, diarrhea, cataracts, trying to ruin in meat and milk, hair loss, and prurigo.	(Ramesh et al., 2003)

1.4.5. As heavy metal and dye removal

Heavy metals can be obtained from Parthenium weed. It has been investigated if nickel and dye absorption efficiency may be removed from industrial wastes by parthenium treated with HCl. Despite pH being a problem, its capacity to absorb color allows it to replace products readily accessible in stores. In tests, heavy metals, including nickel, cadmium, copper, and zinc, can be absorbed by parthenium. Cresol, a phenol derivative produced by parthenium-derived activated carbon, proved more efficient than conventional activated carbon (Patel, 2011). Because parthenium plants offer an unrivalled utility for this undesirable weed plant, heavy metal dyes should be removed utilizing biological sources like them as they are known to cause cancer (Khatak et al., 2016).

1.5. Biological Control of Parthenium

Classical Biological Control

1.5.1. Insects as Classical Biocontrol Agents

The galling stem moth, known as *Epiblema strenuana*, and the leaf-feeding beetle, called *Zygogramma bicolorata*, have both shown great promise in managing parthenium weed. The moth was introduced to control the weed, but its cultures were destroyed because it prefers to lay eggs and develop on other crops (Khatak et al., 2016). The beetle, on the other hand, was brought from Mexico in 1980 and has been tested in both Australia and India. Both the larvae and adults of the beetle feed on the leaves, consuming the terminal and auxiliary buds before moving on to the developing leaf blades. However, the insect's effectiveness is limited because it doesn't have a preference for parthenium over other species, and it also targets sunflowers in India. Within 4-8 weeks, one adult beetle can cause leaf skeletonization, but due to the weed's high reproduction rate, progress has been slow (Rahmat et al., 2011).

1.5.2. Classical Control by Fungal Plant Pathogens

Classical biological control strategy involves using quick-reproducing, efficient aerially-dispersing obligatory parasites, particularly rust fungi, due to their limited host ranges. *Entyloma compositarum*, *Puccinia abrupta* var. partheniicola, *Puccinia xanthiivar* parthenii-hysterophorae (formerly known as *P. melampodii*), and *Plasmopara halstedii* (Farlow) are examples of such fungal pathogens that have been used in this strategy. The two Puccinia species, *Puccinia abruptavar* partheniicola and *Puccinia xanthiivar, Parthenii hysterophorae*, which have been extensively investigated and introduced in Australia, are the most promising traditional biocontrol fungus for this weed. In 1999, Australia imported the Mexican rust pathogen *Puccinia abruptavar* partheniicola as a conventional biocontrol tool to manage parthenium. High to intermediate elevations (1400–2500 m.a.s.l.) are frequent locations for rust, and the disease incidence can exceed 100% in certain areas. The presence of the rust disease on parthenium in different areas indicated variable effects on this weed's morphological traits, with a 42% decrease in seed production capability. Despite a few weakly developed pustules being observed on other niger seeds, host specificity tests against parthenium-related weed and crop hosts revealed that abrupt sporulation was only detected on parthenium (Fauzi et al., 1999; Parker, 1989).

1.5.3. Chemical Control applications of *P. hysterophorus*

Chemical control is an effective tactic in areas without parthenium's natural enemies. Chemical herbicides with the potential to effectively control this plant include chlorimuron ethyl, glyphosate, atrazine, ametryn, bromoxynil, and metsulfuron. In 15 days after spraying (D.A.S.), 2,4-D E.E. (0.2%) and metribuzin (0.25 and 0.50%) it was shown to be more efficient at controlling parthenium, resulting in the population being destroyed and preventing the development of weeds (Khan et al., 2012).Reports suggest that the timing of herbicidal management for parthenium weed is crucial, as it was found to be most effectively eradicated during the rosette stage in areas such as wastelands, non-cropped areas, railway lines, water channels, and highway sides (Khan et al., 2012). Glyphosate and metribuzin were found to be the most effective treatments, showing higher mortality at 4 weeks after treatment for both the rosette and bolted phases, when compared to 2, 4-D, triasulfuron + terbutryn, bromoxynil + MCPA, atrazine + s-metolachlor, atrazine, and s-metolachlor. Pendimethalin was found to be the least effective treatment during both stages of development. Overall, the efficacy of herbicides on parthenium plants with rosette-like growth was more promising than on those with bolted growth. In non-cultivated areas, along railways, and highway sides, spraying a 15-20% concentration solution of common salt (sodium chloride) is adequate for control (Sohal et al., 2002).

1.5.4. Biological Control applications of *P. hysterophorus*

Biological control uses natural enemies to decrease or lessen insect numbers and consequences. This approach is both practical and environmentally responsible. Over the past three to four decades, several biocontrol agents, including microbial illnesses, insects, and botanicals, have significantly controlled parthenium (Ray and Gour, 2012; Watson and Wymore, 1990). Among the various biocontrol strategies, the biological control of weeds by plant diseases has gained popularity as an effective, secure, and environmentally responsible strategy for agroecosystems (Aneja 2009). There are two primary techniques (native or imported), and mass rearing boosts their numbers: the conventional methodology, which includes introducing foreign disease-causing organisms to manage weeds, and the augmentative or bioherbicidal approach. The terms inoculative strategy and innovative approach are used, respectively, in the area of epidemiology (El-Sayed, 2005).

Table 2 Toxicological impacts of *P. hysterophorus* on humans

Sr no.	Body part	Disorder	References
1.	Extremities	Deep pelvic pain, leg pain, numbness in the upper extremities and the desire to urinate	(Maishi et al., 1998)
2.	Skin	neck, eye, elbow, knee pit eruptions, burning and skin pigmentation accompanied by dryness	(Juana et al., 1997)
3.	Heart	chest pain, palpitations and bradycardia	(Batish et al., 2007).
4.	Respiratory organs	palpitations, dyspnea, dry cough and uneasiness	(Demain and Feng, 2000)
5.	Urinary parts	heavy and challenging kidneys, cystitis, blood in the urine, and increased urination	(Velancia et al., 1994)
6.	Anus	Indigestion and diarrhea	(Ahmad et al., 2018)
7.	Abdomen	The extreme gas development, deep pelvic colic that makes you want to urinate, bloated, hard, and fluid-filled abdomen	(Cotugno et al., 2012)
8.	Stomach	Bacterial infection and a full stomach	(Seca et al., 2017).
9.	Head	Having a heavy head, a sore throat, and eczema	(Panwar et al., 2015).

CONCLUSION

Parthenium species are commonly regarded as unwanted weeds that are typically destroyed or burned to promote the growth of primary crops. However, due to their significant pharmaceutical and industrial applications, such as their antibacterial, antidiabetic, and anti-inflammatory properties, these plants have the potential to be converted into a valuable economic resource. Instead of being discarded or destroyed, parthenium could be utilized as a source of valuable chemical and biological agents to benefit the economy. Further research is needed to confirm this concept, but in a world striving for a sustainable economy, it is essential to maximize the potential of all-natural resources, even those considered weeds like parthenium.

Conflict of interest

The authors declared the absence of a conflict of interest.

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