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Allelopathic Effects of Invasive Alien Species *Parthenium hysterophorus* L.

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Abstract

The Asteraceae family includes *Parthenium hysterophorus*. The subtropical regions of the Americas are the original habitat of this invasive noxious weed. It is spreading in India and other Asian countries at an alarming rate. It releases allelochemicals like parthenin into the environment by leaching, volatilization, etc. It has ability to grow very fast. It is branched, annual, erect herbaceous plant with tap root system. Stem is cylindrical with longitudinal lines. The alternating leaves are simple and have deep pinnatifid veins. There are several tiny, hairy flower heads at the very end, called capitulum. In every flower-head, you'll find five tiny seeds called achenes. We are well-versed in the toxic effects of *P. hysterophorus* and would like to prevent an infestation. But managing it through its use for various objectives is better than merely regulating its growth, which won't get rid of it. The practical qualities of *Parthenium hysterophorus* have recently attracted a great deal of attention from researchers.

Keywords: Alien species, Parthenium, weed, effects, control

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Introduction

Allelopathy occurs when certain plants, including microorganisms, emit substances called allelochemicals into the environment. These chemicals can either help or hurt other plants, depending on the situation. Allelochemicals by a variety of mechanisms, including root exudation, volatilisation, residue breakdown, and leaching (Fraenkel, 1959). There is an effect on plant respiration, cell division, elongation, morphology, and permeability of membranes, as well as enzyme activity (Bashar *et al*., 2023). Weir *et al*. (2004) defined allelopathy as the effect of phytochemical substances on other plants or microorganisms, whether this effect is direct or indirect; the term was initially created by Molish (1937). No matter how much work farmers put into eradicating weeds, they continue to pose a problem and reduce crop yields around the world. No amount of time spent studying weeds or developing better methods of controlling them has reduced their impact on soil and environmental production and manageability. As a dangerous weed that poses numerous health dangers to both humans and animals, *Parthenium hysterophorus* has been the subject of extensive research in many parts of the globe, including India. Damage to *P. hysterophorus* was widespread because many specialists used various biological approaches involving insects, beetles, microbes, and specific diseases (Dukpa *et al*., 2020). Allelopathic potential can be found in many different types of plants, algae, bacteria, and fungi. Several pulses were used to study the allelopathic potential of *Parthenium hysterophorus* in this article.

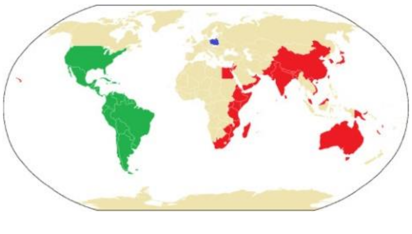

Fig 1. *Parthenium hysterophorus* is found all over the world. In this weed map, the green areas denote its native range, the red areas its invasive range, and the blue areas its temporary populations in Europe (Bajwa *et al*., 2016).

Origin and Distribution of *Parthenium hysterophorus*

Toxic tolerances, edaphic preferences, phenotypic plasticity, range size, life history, geographical distribution, environmental indicator values, climatic tolerances, habitat types, and high dispersal ability are some of the beneficial ecological traits that invasive plants possess (Gioria *et al*., 2023). While these traits are common among invasive species, they are not universal. Environmental characteristics, however, provide the clearest picture of the alien's dominance over local flora. This weed's invasiveness and competitive advantage are supported by several ecological features. Dukpa *et al*. (2020) and Bashar *et al*. (2023) found that allelochemicals emitted by this weed hinder both germination and the growth of neighbouring plants. Although it originally originated in the North and South American subtropics, it has spread to Asia, Africa, and Australia in the past half-century.The plant has now colonised every continent and island in the world. Its rapid expansion has been noticed in several Asian nations, including India, Bangladesh, Pakistan, China, and others. Some nations, like Pakistan, South Africa, Ethiopia, India, and Australia, have a serious infestation problem due to its rapid spread. It arrived in the 1950s, when American cereal and grass seed shipments began making their way to Oceania, Africa, and Asia (Bhowmik and Sarkar 2005).

Spread in India

It wasn't until 1956 that *Parthenium hysterophorus* was recorded in India, however it may have arrived in 1910 along with diseased cereal germplasm. Initially discovered in 1955 in India (Rao, 1956), the weed is currently present globally (Yaduraju, 2005) and covers around 35 million hectares of land (Kumar and Varshney 2007). There have been reports of *Parthenium hysterophorus* infestations in every state of India, albeit to varying degrees. Almost every Indian state, including Uttar Pradesh, Madhya Pradesh, Bihar, and Andhra Pradesh, is severely affected by this weed (Kumar 2014). Although it is prevalent in every state, *Parthenium hysterophorus* is particularly problematic in several states with extensive agricultural, non-cropping, and grazing terrain (Kumar 2012). One of the world's most contaminated countries is India right now. Similarly, reports of Parthenium infestation in southern Indian national wildlife sanctuaries are not uncommon (Evans, 1997). Parthenium colonised pastures, roads, and farms. Furthermore, it rapidly depletes soil nutrients and competes with land-based crops. According to Ellis and Swaminathan (1969), this weed was first identified in Uttar Pradesh in Pantnagar, which is across from the railway station. Since then, it has expanded to a few agricultural areas, the Rae-Bareily district, and the Jhansi areas. Its most prolific growth occurs in specific regions, notably in the western part of U.P. There is an abundance of weed on the banks and basins of rivers, as well as on neighbouring agricultural and abandoned land (Murthy *et al*., 1977). The Western U.P. region, including Pilibhit, Puranpur Tehsil, Bisalpur Tehsil, Shahjahanpur, Mala and Deoria forest (Pilibhit), Badaun, Bareilly, Etah, Aligarh, Hathras, Firozabad, Mainpuri, Mathura, Moradabad, Meerut, Bijnor, Rampur, Jyotiba-Phule Nagar, Baghpat, Muzaffarnagar, Saharanpur, and other regions (Prakash *et al*., 2017).

Taxonomy and Botanical Description of *Parthenium hysterophorus*

Asteraceae is home to the *P. hysterophorus* weed, a huge and unique species found all across the globe (Khaket *et al*., 2015). Congress grass is also known as Demoina weed, ragweed Parthenium, Parthenium weed, Sacramento grass, bitterweed, feverfew, false ragweed, and Santa Maria. One of the most invasive and harmful weeds is hunger weed, also known as carrot weed or broom bush in India. There are more than 32,000 species of flowering plants in this family, which is scattered all over the globe. The order Asterales includes more than 1900 genera (Mandel *et al*., 2019).

Taxonomic classification

The taxonomic classification of *Parthenium hysterophorus* is:

Kingdom: Plantae
Phylum: Streptophyta
Class: Magnoliopsida
Order: Asterales
Family: Asteraceae
Genus: Parthenium
Species: hysterophorus

Morphology

The herbaceous plant *Parthenium hysterophorus* stands upright, has many branches, and only lives for one year. In its early stages, it grows a clump of leaves close to the ground. It reaches a height of 1.5 to 2 meters and develops numerous branches on the upper half of the plant as it matures (Dhileepan 2007 & Dhileepan *et al*., 2018)..

1. Root

This annual weed has a deep taproot and matures quickly.

2. Stem

The cylindrical and solid stem has longitudinal lines that match the extent of the midrib of the leaves and exhibits more or less flutes. Mature stems are covered with tiny, soft hairs called hirustle and have a greenish hue. As they mature, the stems grow considerably harder.

3. Leaves

There are two distinct varieties of this plant with stalked leaves that are up to 2 cm long and placed alternately. It creates rosette habitat when it's young. A basal rosette of bright green, finely lobed leaves, 8–20 cm long and 4–8 cm broad, is produced by the sprouting young plant. The rosette stage has the potential to grow to a maximum length of 2.5 m even in adverse conditions (Tiku *et al*., 2014). Alternate, simple, and heavily pinnatified leaves. In contrast to the narrow and deeply divided blades of the top leaves, the lower leaves have a wider and more broadly formed blade that is 11–15 cm long and 6–10 cm wide. Close to the surface, short and stiff hairs cover the abaxial surface of leaves.

4. Flowers

At the very tip of each branch are a number of tiny, slightly hairy flower heads called capitulum, which are arranged in clusters called terminal panicles. On a stalk called a pedicel, each flower-head is carried. Embedded within the capitulum, which measures 3-5 mm across, are ray florets that are 0.3-1 mm long and have an off-white or white hue. Five productive ray florets are typical for a head, while six or eight may be present on rare occasions. Additionally, they include a cluster of tiny, green bracts (an involucre) encircling two rows of tubular florets (flowers that range in size from fifteen to sixty in diameter) in the centre. Although it can bloom at any time of year, the rainiest months are when you're most likely to see it.

5. Seeds

There are five little "seeds," or achenes, that are formed by every flower-head. The compressed black seeds, which are around 2 mm in size, are produced by thousands of branches that grow in independent clusters. A flat bract, two straw-colored papery structures (really dead tubular florets), and two or three minute scales called pappus approximately 0.5-1 mm in height make up the black obovoid seeds, which are 1.5 mm broad and 2 mm long.

A steady supply of water, animals, and machines are necessary for its seed to germinate.

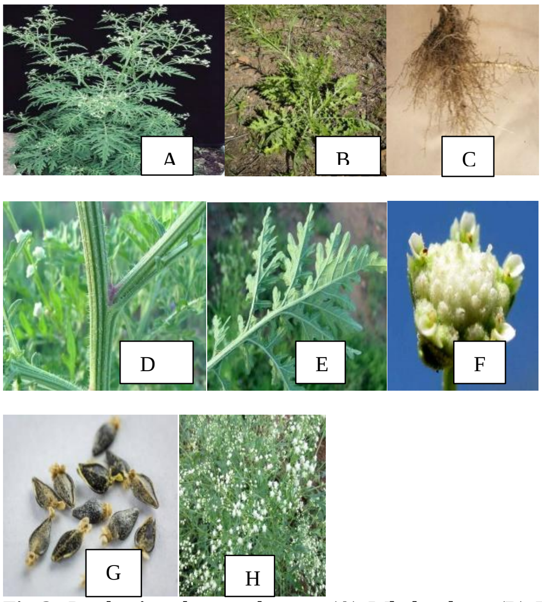

Fig 2. *Parthenium hysterophorus* . (A) Whole plant, (B) Rosette stage, (C) Root, (D) Stem, (E) Leaves, (F) Flower, (G) Seeds, (H) Flowering stage.

Seed germination

Parthenium flowers appear 24-48 days after seedlings are germinated. This is something that can happen throughout the year. Its seed germination is best accomplished with a day/night temperature cycle of 21/16◦C. Additionally, its seeds have a long storage life in soil, lasting anywhere from four to six years. Also, contrary to popular belief, buried seeds have a far longer shelf life than surface-planted ones (Adkins and Shabbir, 2014).

Life Cycle of Parthenium

It is mostly propagated by seeds and is an annual herbaceous plant. One reason *P. hysterophorus* is so effective as an invasive plant is that it can generate a lot of seeds, and those seeds can stay viable for up to five years (Bajwa *et al*., 2016). Over the course of its lifetime, a fully grown plant can deposit as many as 25,000 seeds into the earth (Van der Laan *et al*., 2008) (Cowie, 2020).

How it spreads

Its rapid growth, adaptability to photothermal conditions, short life cycle (90 to 120 days), lack of natural enemies (generally), and ability to spread through waterways and roads are just a few of its many characteristics that allow it to spread very quickly (Naive *et al*., 1996; Dhileepan and Mc Fayed, 2012).Vehicles or seed lot contamination are often considered as possible vectors for the spread of parthenium (Shabbir *et al*., 2012). Pseudomonas hysterophorus invades due to multiple circumstances. Germinating at temperatures between 12˚C to 27˚C, it can withstand salty environments, and its deep root structure lets it live in low-humidity regions. It can also grow in a broad range of climatic conditions (Bashar *et al*., 2021, Chib *et al*., 2013). Fig 3. *Parthenium hysterophorus* L.'s life cycle and how its seeds are dispersed (Jamil *et al*., 2021).

A few key factors that contribute to the rapid spread are:

• Possibility of alleopathy

• Fast growth rate • Unappealing to animals

• High reproductive potential

(i) High reproductive potential:

Parthenium hysterophorus has an enormous seed bank, with an estimated 2,000,00 seeds/m2 on barren lands and agricultural fields (Joshi, 1991) and as many as 15–25,000 seeds per plant (Naive, 2003). Parthenium seeds are able to persist for an extended length of time even when exposed to severe environments. This weed's rapid spread is facilitated by these traits. Parthenium seeds, provided they have access to adequate moisture, can germinate at any season (Williams and Grovers, 1980).

(ii) Fast growth rate:

An annual herbaceous weed, it grows rapidly. Typically, partheniums begin to bloom as early as four to eight weeks of age and continue to do so for a number of months. The life cycle of the weed can be completed in four to five weeks under less than ideal circumstances, such as when exposed to salt or drought.

(iii) Allelopathic potential:

This poisonous weed uses allelopathy to inhibit the growth of neighbouring plants. Important commercially significant crops that are nearby are unable to germinate or thrive due to leachate and extract of leaves and inflorescence. Researchers Kumari *et al*. (2014) found that spraying crop plants with an aqueous extract of Parthenium significantly lowered physiological and biochemical indices. It is known that parthenium can reduce agricultural crop yields by 40–80% due to its significant allelopathic effects on other plants.

(iv) Unpalatable to animals:

The animals do not enjoy eating *Parthenium hysterophorus* . *Parthenium hysterophorus* has a strong scent and a bitter taste, hence animals usually avoid it (Javaid and Anjum, 2005). Livestock in regions infested with *Parthenium hysterophorus* pose a significant health risk, according to earlier research conducted in India. Unless mechanically removed, its population will continue to rise despite the fact that it is tasteless and so useless as animal feed. A natural product-based herbicide for weed control might be developed using the allelopathic chemicals isolated and identified from *P. hysterophorus* (Motmainna *et al*., 2021). Important chemicals identified in Parthenium plants include parthenin, hysterin, hymenin, and ambrosin (Patel, 2011).

In the meantime, there are a variety of possible allelochemicals in aerial sections (e.g. leaves) of Parthenium weed have been confirmed by several earlier studies; among them p-anisic acid ($C_8H_8O_3$), p-coumaric acid ($C_9H_8O_3$), caffeic acid ($C_9H_8O_4$), ferulic acid ($C_4H_4O_4$), fumaric acid ($C_4H_4O_4$), p-hydroxybenzoic acid ($C_7H_6O_3$), neochlorogenic acid ($C_{16}H_{18}O_9$), protocatechuic acid ($C_7H_6O_4$), aerulic acid, chlorogenic acid ($C_{16}H_{18}O_9$) and vanillic acid ($C_4H_4O_4$) are the most important (Malarkodi and Manoharan, 2013 & Dhawan and Gupta, 2017) sprouting and development of a plant species in abundance, natural plants are included and different crops and pasture species can be inhibited by these chemicals (Singh *et al*., 2005).

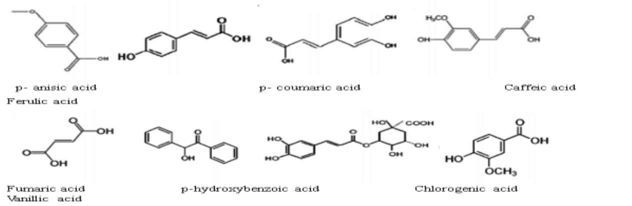

Fig 4. The molecular structure of some major components of *Parthenium hysterophorus* L. (Patel, 2011).

The Harmful Effects of *P. hysterophorus*

(a) On Crops

Soil infections caused by Parthenium weeds reduced the germination time, growth rate, and yield of traditional crops in India. This is because the leaves of these weeds contain caffeic acid and p-coumaric acid. These are what keep the growth rate from increasing (Kanchan and Chandra, 1980). Another study found that Parthenium leaf extracts significantly disrupted the growth of Zea mays seedlings and that they influenced the elongation of crucifer seedlings (Singh *et al*., 2005). Due to its allelopathic properties, Parthenium hinders the germination and growth of various agricultural crops, including wheat, rice, maize, pigeon pea, sorghum, and black gramme. This can result in a yield reduction of up to 40% (Dukpa *et al*., 2020). The germination and growth of three different rice varieties (Hira dhan, BRRI dhan-28, and BRRI dhan-29) were studied in Bangladesh by Bhowmick *et al*., (2024) to determine the allelopathic effects of *Parthenium hysterophorus* L. leaf extracts. Under regulated conditions, *P. hysterophorus* leaf extracts were made at varying quantities and then applied to rice seedlings. Significant variations among rice varieties ($p < 0.05$) were observed in the results, which demonstrated that seed germination and growth were hindered by low doses of the extracts.

According to Bashar *et al*. (2023), natural molecular herbicides are more eco-friendly and cost-effective than synthetic chemical herbicides when it comes to eradicating weeds in agriculture fields. Within this framework, a study was conducted to determine whether *Parthenium hysterophorus* L. possessed any allelopathic properties and, if so, which phenolic compounds were responsible for these effects. Additionally, the LC-MS study showed that 7 phenolic compounds were present in the *P. hysterophorus* leaf extract, which caused the allelopathic impact to suppress the evaluated crops and weeds. The recent study found that *P. hysterophorus* leaves have allelopathic potential against both crops and weeds. These leaves could one day be employed as a helpful natural pesticide to control weeds and extend the lifespan of crops.

(b) On Soil Microflora

Nitrosomonas and other nitrifying bacteria, as well as Rhizobium and Azotobacter, are known to have their growth and activity potential inhibited by parthenium. Rhizobium, Nitrosomonas, and Azotobacter are all inhibited in their growth by an aqueous extract of Parthenium. It decreased the Rhizobium-legume symbiosis-influencing leghemoglobin content of root nodules. The chemical component of leaf and root leachates inhibits nitrate synthesis (Sukhada and Jaychandra, 1981).

(c) On Animals

Livestock can get dermatitis and other skin problems from the toxic Parthenium weed (Gunaseelan, 1998). Symptoms in animals include a loss of pigmentation in the skin, dermatitis, mouth ulcers accompanied by excessive salivation, and diarrhoea. This weed can be fatal to animals in large quantities. Animals' immune systems are compromised because parthenium extract lowers their overall white blood cell count.

(d) On Human Beings

For certain people, the components of the parthenium plant can be harmful. According to estimates, over 70% of those residing in areas affected by the weed experience sensitivity.The sensitivity of females is likely to exceed that of males. Humans are susceptible to a wide range of allergic reactions to Parthenium, including dermatitis, hay fever, asthma, and bronchitis, among others. Ambrosin, parthenin, coronopilin, and tetraneuris are the main allergens in this plant. People with asthma are reported to be triggered by its pollen grains. This plant is both sites specific and capable of causing systemic dermatitis when handled physically. There are five distinct forms of Parthenium dermatitis based on clinical presentation:-

1. The classical pattern
2. The chronic actinic dermatitis (CAD)
3. The mixed pattern (classical and chronic actinic dermatitis pattern combination)
4. The photosensitive lichenoid eruption
5. The prurigo nodularis like pattern (Bailey, 1960.).

The Beneficial Effects of *P. hysterophorus*

(a) Use as Medicinal plant

Amoebic dysentery is treated with root bisque. Reduced malignant activity in mouse cells was seen at sub-lethal dosages of parthenin extract. According to research conducted by Sharma and Bhutani in 1988, parthenium has the potential to alleviate neuralgia, hepatic amoebiasis, and even some forms of rheumatism. In the United States, it is used topically for the treatment of numerous ailments. To rid animals of fleas, Jamaicans use the elixir (Dominguez and Sierra, 1970).

(b) Antioxidant

The methanolic extracts of *Parthenium hysterophorus* exhibited a strong antioxidant activity. Hence, it has potential as an antioxidant in its natural form. When it becomes commercially available, this naturally occurring antioxidant will be able to supplant synthetic antioxidants, which pose health risks to humans (Khan *et al*., 2011). After studies showed that synthetic antioxidants are much more harmful than naturally occurring antioxidants, it became clear that the former was the superior choice.

(c) Antifungal

Parthenium, as previously stated, has antifungal effects on various species of fungi. Because of this property, parthenium has the potential to treat a variety of fungal infections in both humans and animals. *Parthenium hysterophorus* has a sequestoterpene lactone that is effective against dermititis-related fungi and other skin ailments (Rai, 2003).

(d) Antitumor

The methanolic flower extract of *Parthenium hysterophorus* showed anticancer effects in mice with transplantable lymphocytic leukaemia. Glutathione, cytochrome P-450, glutathione transferase, and UDP-glucuronyl transferase levels, among other neoplastic indicators, changed significantly, which slowed tumour growth and increased animal longevity (Mukherjee and Chatterjee, 1993).

(e) Antimicrobial

The antibacterial and antifungal properties of *Parthenium hysterophorus* are highly evident. It can also suppress the growth of certain bacteria and fungi, including Aspergillus niger, Fusarium oxysporum, Candida albicans, Staphylococcus aureus, Escherichia coli, and rhizosphere flora including Rhizobium and Azotobacter.

(f) Pesticidal

The presence of phenolic chemicals, such parthenin, gives parthenium its insecticidal effect. A number of insects, including Spodoptera litura, Meloidogyne incognita, Cassia tora, and Callosobruchus aculatus, as well as their larvae, are killed by parthenin, the principal volatile component of parthenium. Propenyl parthenin derivatives, saturated lactone, and pyrazoline adduct exhibited exceptional nematicidal and phytotoxic effects (Datta and Saxena, 2001).

(g) Larvicidal

Researchers have found that Parthenium has larvicidal effects, making it a potential tool for controlling the larvae of pest insects like mosquitoes and aphids, which can cause harm to crops and people, respectively. The effectiveness of an aqueous extract of Parthenium against mosquito larvae, including Aedes aegypti (Kumar, 2011). The reproductive capacity and lifespan of Lipaphis erysimi were dramatically reduced in the weed extract (Sohal, 2002).

Control of *P. hysterophorus*

Several methods exist for controlling *P. hysterophorus* . Below, we'll go over a few of the techniques.

1. Biological methods

Biological weed control is the intentional manipulation of natural enemies by humans to eradicate noxious weeds. While full eradication of noxious weeds is obviously impossible, the goal of biological control is to keep their populations below what they would be in the absence of the bio-control agent (Veena *et al*., 2012).

1.1 Control by competitive plants

Cassia sericea, Amaranthus spinosus, Cassia tora, and Tagetes spp. are all examples of competitive plants that can dominate their habitat and limit the growth of other plants nearby. Therefore, *P. hysterophorus* can be controlled using this method (Anjum *et al*., 2005 & Bezuneh, 2015).

1.2 Control by microorganisms and pathogens

Some microorganisms, including viruses, fungus, and bacteria, can produce poisons that are lethal to plants. According to Jayaramiah *et al*. (2017), mycoherbicides are poisons made by a class of fungi, while bio-herbicides are poisons made by microbes. Fungi have been the primary subject of research, as opposed to other types of creatures. The specialists from the International Institute of Biological Control conducted a comprehensive assessment in several countries, including Cuba, Trinidad, and Mexico, and they discovered 26 different kinds of fungi on Parthenium. Professionals also identified several species, like P. melampodi and Entyloma compositarum, that are more suited for biological control.

Bacteria *Ralstonia solanacearum* and *Xanthomonas campestris* were found to attack the Parthenium. These microbes invade plants through the roots. In addition to Parthenium, *R. solanacearum* infected crops like potato, brinjal, tomato, and tomato. Its soil survival time is up to six months.

1.3 Control by insects

Zygogramma bicolorata, a leaf-feeding beetle, Listronotus setosipennis, a stem-galling moth, and Epiblema strenuana were brought to Australia to combat *P. hysterophorus* (Dhileepan, 2003).

1.4 Control of Parthenium by allelopathic grass

A study conducted by Jagaid *et al*. (2005) found that allelopathic grasses such as *Dichanthium annulatum, C. pennisetiformis*, and *S. halepense* can inhibit germination and regulate seedling growth of the tropical weed *P. hysterophorus* . Javaid and Anjum (2006) found that S. halepense had the least inhibitory effect compared to *D. annulatum* and *C. pennisetiformis* water extracts. The extract from the plants' shoots was more detrimental to the development and germination of Parthenium seedlings than the extract from the roots.

Table: List of allelopathic plants used for suppressing the growth and germination of the weed (*P. hysterophorus*)

Sr. No.	Botanical name	Common name	Family	Part used	References
1.	*Imperata cylindrica*	Cotton wool grass	Poaceae	Root and shoot	Anjum *et al.*, (2005)
2.	*Desmostachya bipinnata*	Halfa grass	Poaceae	Root and shoot	Anjum *et al.*, (2005)
3.	*Azadirachta indica*	Neem	Meliaceae	Leaves	Shafique *et al.,* (2005)
4.	*Ficus benghalensis*	Indian banyan	Moraceae	Leaves	Shafique *et al.,* (2005)
5.	*Melia azedarach*	Chinaberry tree	Meliaceae	Leaves	Shafique *et al.,* (2005)
6.	*Mangifera indica*	Mango	Anacardiaceae	Leaves	Shafique *et al*., (2005)
7.	*Syzygium cumin*	Black Plum	Myrtaceae	Leaves	Shafique *et al*., (2005)
8.	*Dichanthium annulatum*	Sheda grass	Poaceae	Root and stem	Javaid and Anjum, (2006)
9.	*Helianthus annuus L.*	Sunflower	Asteraceae	Root and stem	Javaid *et al.,* (2006)
10.	*Sorghum bicolor L.*	Sorghum	Poaceae	Root and stem	Javaid *et al*., (2006)
11.	*Oryza sativa L.*	Rice	Poaceae	Root and stem	Javaid *et al*., (2006)
12.	*Cenchrus pennisetiformis*	Slender buffelgrass	Poaceae	Shoot and root	Javaid and Anjum, (2006)
13.	*Sorghum halepense*	Johnson grass	Poaceae	Shoot and root	Javaid and Anjum, (2006)
14.	*Cassia occidentalis*	Coffee senna	Fabaceae	Shoot	Knox *et al*., (2010)
15.	*Eucalyptus*	Gum tree	Myrtaceae	Leaves	Patel, (2011)
16.	*Cassia tora*	Tora	Fabaceae	Leaf and stem	Devi *et al.,* (2013)
17.	*Cassia sericea*	Silver cassia	Fabaceae	Leaf and stem	Devi *et al*., (2013)
18.	*Mimosa pudica*	Touch me not	Fabaceae	Leaf and stem	Devi *et al*., (2013)
19.	*Tephrosia purpurea*	Wasteland weed	Fabaceae	Stem, root and leaf	Bhatnagar, (2018)
20.	*Digitaria milanjiana*	Madagascar crabgrass	Gramineae	Shoot	Shabbir *et al*., (2019)
21.	*Chloris gayana*	Rhodes grass	Poaceae	Dry biomass	Shabbir *et al*., (2019)

2. Physical controls

Manual removal of the Parthenium is possible prior to flowering and seed set. One of the best ways to accomplish this goal is by using this strategy. The rosette stage, just before parthenium weed releases seeds, was ideal for ploughing. Hand weeding is another labour-intensive mechanical control method (Kalidas, 1981). To manage the weeds, burning is another option to explore. It has also been demonstrated that this burning approach is highly ineffective. The first reason is that it uses up a lot of energy and other resources, and secondly, it harms the other plants in the area that provide food (Ray and Gour, 2012).

3. Chemical controls

When Parthenium's natural enemies aren't around, chemical control becomes necessary. Glyphosate, chlorimuron-ethyl, ametryn, atrazine, bromoxynil + 2-methyl-4-chlorophenoxyacetic acid, and metsulfuron are the most widely used and effective chemical herbicides (Javaid and Anjum, 2006). It was found that the weed could be effectively controlled in situations like dry grass, next to railway tracks, on roadside vegetation and in water channels when it was in its rosette stage. The most straightforward approach to controlling *P. hysterophorus* has been suggested as spraying a solution of common salt at a concentration of 15-20% (Jayaramiah *et al*., 2017). Both glyphosate and isoproturon kill *P. hysterophorus* , however glyphosate is more effective (Shabbir, 2014). The current user is more worried than ever before due to the widespread use of chemicals. Carcinogenicity, persistent toxicity, and environmental pollution are only a few of the harmful effects that have limited its use (Javaid, 2010).

But managing it through its use for various objectives is better than merely regulating its growth, which won't get rid of it.

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