Review

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Biological management of allelopathic plant *Parthenium* sp.

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Abstract: Globally, weeds have been considered as a major threat and act as a hindrance to crop production, even though the farmers put tremendous efforts to eliminate the weeds to get a better yield. Weeds stayed a steady threat to productivity and manageability of soil and environment, regardless of many years of research and advances in management practices. *Parthenium hysterophorus* is widely studied all around the world including India as a noxious and an unsafe weed responsible for many health risks in humans and animals. Many experts employed different biological methods using insects, beetle, microorganisms, and certain pathogens, which caused a broad dispersal damage to *P. hysterophorus*. Biorational weed control is also offered by allelopathy through the production of allelochemicals from the leaf, blossoms, grains, nuts, bud, berry, trunk, and organization of living or decaying plant substance. Allelopathy is the most realistic method to control the weeds as well as different plants. Lately, there has been a proliferation of curiosity to research on plant allelopathy to control weeds in agro-ecosystems. The successful management of this weed can only be achieved by an integrated approach with allelochemicals as a crucial aspect.

Keywords: allelopathy, allelochemical, biological control, *Parthenium hysterophorus*

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1 Introduction

A basic definition of a weed from a human point of view would be “an undesirable plant”, and this normally implies that a weed in one place may not be a weed in another (Wubneh 2019). Weeds are not constantly accommodated into a similar classification of “pests” as insects and other invertebrate or vertebrate pests. Most weeds do not affect humans directly, and their threat to humans is not severe. But some weeds such as *Parthenium hysterophorus* have a great health effect on humans (Naidu 2012). They cause problems to the human respiratory system and also induce allergies in some people.

Any organism that is harmful to humans is known as a pest. In line with this, weeds are essential pests that must be paid attention to since they occupy open-air spaces in the community environment, for example gardens, parks, yards, lawn, scenes, and landscapes (Matusova et al. 2004). Generally, weeds have the capability to invade, proliferate, and survive among the incorporating desired plants. Numerous weeds can likewise survive in stressful environment conditions (Msafiri et al. 2013).

In the past few decades, invasive plants have been eliminated with the application of synthetic (chemical) herbicides. Such kinds of herbicides can cause environmental damage, and they also harm living organisms including humans. With the excessive use of chemical herbicides, the invasive herbs become more resistant to them. Hence, we can consider the use of bio-herbicides a positive, environmentally and economically sustainable alternative (de Miranda et al. 2014).

Generally, the weeds are of three types based on the morphology of the plant, such as grasses, sedges, and weeds. Based on their life cycle, they are annual, biennial, and perennial (Naidu 2012). *P. hysterophorus* is an annual herb that takes over the weak pastures with thin vegetation. Empty places near roadsides and around play area are readily colonized and disturbed by *P. hysterophorus*. It can also colonize some trees such as brigalow and gidgee and softwood scrub soils.

The existence of *P. hysterophorus* decreases the stability of an improved grazing land establishment, which also reduces pasture production. *P. hysterophorus* is thought to be a natural hybrid of *P. confertum* and *P. bipinnatifidum*, which belongs to Asteraceae family.

P. hysterophorus can flourish in a hostile environment and suppress the growth of other native species due to its allelopathic effect. Depending on the distinct environmental conditions, different quantities of allelochemicals may also be released, which inhibits seedling development (Msafiri et al. 2013). This review tries to report on the current status of the weed and to analyse the findings of both the published and unpublished research studies on the biological control of *P. hysterophorus*.

2 Status of weed

P. hysterophorus is a weed of worldwide presence, considerably found in Asia (India, Taiwan, Bangladesh, Pakistan, Vietnam, Israel, Nepal, Bhutan, Sri Lanka, and southern China), Africa (Mozambique, Ethiopia, Kenya, South Africa, Swaziland, and Somalia), Pacific, and Australia. It is usually known as congress grass, carrot weed, and broom bush in India. Similarly, in USA the experts refer to it as feverfew and false ragweed (Mtenga et al. 2019). Aside from reducing the crop yield and plant biodiversity, it is considered the worst weed that makes humans and animals vulnerable to the diseases associated with it (Kumar 2016).

P. hysterophorus infestation is increasing rapidly in India and may be more serious than reported here. It was in 1951 that the *Parthenium* weed was first discovered in Poona, Maharashtra. Around 1972, it reached as far as Kerala in the south and Kashmir in the north. Later, in 1979 it expanded and advanced till Assam. Currently, it can be all over the subcontinent. In fact, it infests about 5 million hectares in Karnataka state, making it the most dominant weed in the area (Singh et al. 2013). Initially, *Parthenium* was brought from USA under PL/480 plan, as India was facing drought conditions for 4 years and was forced to buy any kind of grain like wheat. At that time, wheat was contaminated with the noxious weed *Parthenium*. Particularly in India, *P. hysterophorus* has managed to penetrate and thrive in regions of severe climatic conditions. Its presence is recurring in the coastal regions of Tamil Nadu. Presently, *P. hysterophorus* has not spared a single state in India. It has managed to accomplish prime stature among the weeds in India and Australia within a short span of time due to

its rapid multiplication, fast growth and ability to rival other native flora (Kumar 2014).

3 Morphology of *Parthenium* weeds

P. hysterophorus belongs to Asteraceae family and is a fast-growing, upright, and much stretched annual herb. It has the potential to grow rapidly till the height of 0.50–1.50 m. It can grow up to 2 m in great soils (Laan et al. 2008). Throughout its life, *P. hysterophorus* exhibits two particular stages: the vegetative stage (juvenile) and the reproductive stage (adult). The vegetative stage shows a rosette, pinnatisect, radical, and dark green leaves without flowering. The lower leaves are extensive, which spread on the floor and cover all the vegetation which is situated below. The reproductive stage is upright, stretched with profound taproot system (Msafiri et al. 2013; O'donnell et al. 2005).

The stems are usually hairy, octangular, branched, and woody as the plant matures. The leaf is usually simple and alternate, and it is little smaller near the pinnacle of the limb (branches) (Wahab 2005). The blooms are around 4 mm and rich white, emerging from leaf forks. A huge amount of pollen grains is produced, which are pollinated by the wind. Each bloom produced wedge-shaped black seeds. The fruit of *P. hysterophorus* is known as cypsela, which is light brown in colour in its young days and later turns dark brown (mature). The fruit takes up the oblate and ellipsoid shape (OEPP/EPPO 2014).

Water, wind, animals, vehicles, etc., are the major agencies of seed dispersal. Vehicles and farm machinery are responsible for long-distant dispersal (Saha et al. 2018). Vitality of seeds and their dispersal is also a major concern that must be controlled. Seeds do not undergo dormancy period, and it can germinate any time when moisture is present (Jeyalakshmi and Valluvapardasan 2010).

4 Harmful effects of *P. hysterophorus*

P. hysterophorus is widely regarded as the most vicious weed due to its toxic effects both to humans and to biodiversity (Kaur et al. 2014) that are discussed below.

4.1 Effect of *P. hystero-phorus* on ecosystem

P. hystero-phorus can disturb the natural ecosystems. There has been an incident in which *P. hystero-phorus* has altered the total habitat in native Australian grasslands, open river banks, woodlands, and flood plains (Chembolli and Srinivas 2007). It conquered 2 million hectares of farmlands in 1991–2000, whereas it conquered 14.25 million hectares in 2001–2007 in India. *P. hystero-phorus* prefers wastelands, gardens, playgrounds, flood plains, woodlands, agricultural field, urban areas, overgrazed pastures, industrial areas, roadsides, railway side, and residential plots to develop itself (Javaid and Adrees 2009). Furthermore, the minimized pasture cover and the drought create the ideal situation for the *Parthenium* weed to form itself. This weed is dominant in clay loam, alkaline soils despite having the potential to grow in any types of soil (Kaur et al. 2014; Bharti et al. 2018).

4.2 Effect of *P. hystero-phorus* on crops

The presence of chemicals such as parthenin, hysterin, hymenin, and ambrosin in *P. hystero-phorus* enforces strong allelopathic effects on various crops. In most dicot and monocot plants, the parthenin inhibits germination and radicle growth. Later, it enters the soil through the decaying leaf debris (Saini et al. 2014). The nodulation in legumes is also affected by *P. hystero-phorus*, mainly due to the hindrance of activity of nitrogen-fixing bacteria, such as *Azospirillum*, *Azotobacter*, *Actinomycetes*, and *Rhizobium* (Kaur et al. 2014).

P. hystero-phorus generates huge numbers of pollens (624 million per plant). These pollens in groups of 600–800 grains are transported away to a short distance. It suppresses fruit growth in tomato, brinjal, and beans after it lands on the vegetative and stigmatic surface in the floral part of the plants. In India, it has been reported that *Parthenium* is responsible for a 40% decrease in the yield of agricultural crops (Meena et al. 2017). A survey in Bangladesh indicated that *P. hystero-phorus* can be found in different types of lands such as farmstead, fallow land, orchard, low land, and railway track (Khaket et al. 2015).

The loss in sorghum grain yield was reported to be 40–97%, when *P. hystero-phorus* was not considered all over the season (Tamado et al. 2002). Its allelopathic conditions hampered the germination and growth of agricultural crops such as wheat, rice, maize, pigeon pea, sorghum, and black gram (Meena et al. 2017).

4.3 Effect of *P. hystero-phorus* on animals and humans

P. hystero-phorus is responsible for causing inflammation (dermatitis) in horses and cattle. It can also cause mouth ulcers, and 10 to 50% of these weeds in the diet can even kill the cattle (Veena et al. 2012). There have been reports of the deaths of buffalo, cross-bred calves, bulls, and calves when *P. hystero-phorus* was fed to them. Additionally, these animals were noted to develop severe dermatitis (Kaur et al. 2014). Furthermore, it is responsible for diseases such as anorexia, diarrhoea, alopecia, eye irritation, and hay fever. In human beings, swelling and itching in mouth and nose were observed when body was exposed to pollens. Furthermore, it was also observed to cause asthma (allergic bronchitis) in the later stages. If the human body is exposed to the plant, it can lead to dermatitis, often causing pain in all parts of the body (Kaur et al. 2014).

5 Chemical constituents of *P. hystero-phorus*

P. hystero-phorus contains a large amount of terpenoids, flavonoids, proteins, volatile oils, carbohydrates, saponins, tannins, glycosides, steroids, lignins, organic acids, sugars, amino acids, and other phenolic compounds (Shabbir 2014; Bezuneh 2015). A bitter glycoside parthenin and sesquiterpene lactones (SQL) are the major chemical constituents of *P. hystero-phorus*. All the parts of *P. hystero-phorus* including pollen and trichomes contain SQLs (Patel 2011). Parthenin, ambrosin, and hymenin are observed to be the offender behind the threatening role of this weed in inciting health hazards (Wubneh 2019). A report from various examinations showed the presence of trace, minor, and major volatile oils (essential oils) extracted from various parts of *P. hystero-phorus* (Roy and Shaik 2013), which are shown in Table 1.

6 Management of *P. hystero-phorus*

P. hystero-phorus can be controlled in several different ways. Some of the methods are discussed below.

6.1 Biological methods

The control of weeds by the biological method is the deliberate manoeuvre of the natural foes by the man to

Figure 1: Schematic representation of the management of *P. hysterophorus*.

control harmful weeds (Figure 1). Biological control does not aim to completely eradicate the harmful weeds, but rather aims to maintain its number less than the average that would occur when the bio-control agent is absent (Veena et al. 2012).

6.1.1 Control by competitive plants

The competitive plants such as *Cassia sericea*, *Amaranthus spinosus*, *Cassia tora*, *Tagetes* spp. can conquer their environment and restrain the development of other plants in the vicinity. Hence, this technique can be applied to control *P. hysterophorus* (Anjum et al. 2005; Bezuneh 2015). India has been a pioneer in carrying out the research. By using competitive plants, not many countries have been able to bring about a significant improvement to the biological method (Sahrawat et al. 2018). Nevertheless, in Australia, plants such as bluegrass, Floren bluegrass, buffelgrass, and butterfly peagrass were found to control the development of *Parthenium* weed (Devi et al. 2013). In USA, Johnson grass, Cogan grass, Barnyard grass, *Ipomoea* species, *Senna obtusifolia*, and other grasses were found extensively on barren land and agriculture land instead of *Parthenium*. Some plant species from South Africa and Pakistan (*Panicum maximum*, *Digitaria eriantha*, *Imperata cylindrica*, *Cenchrus*

pennisetiformis, and *Sorghum halepense*) have been recorded to rival or challenge the *Parthenium*.

In India (Madhya Pradesh), some plant species have been known to replace *P. hysterophorus* by diverse methods. For example, *P. hysterophorus* was naturally replaced by *Cassia tora*, commonly called “Chakoda”, in Madhya Pradesh. This method involves dissemination of *C. tora* seeds in *P. hysterophorus*-infested area. Plenty of seeds of *C. tora* can be found during the month of March and April (Kumar and Varsheny Jay 2007). In the protected districts of Madhya Pradesh, the application of marigold was recommended for controlling the growth of *P. hysterophorus*. By using this method, numerous *P. hysterophorus*-plagued sites have been commanded.

6.1.2 Control by microorganisms and pathogens

Biological control through pathogens is a practice in which the weeds can be controlled using the pathogens. Organisms such as fungi, bacteria, and viruses are capable of producing toxins strong enough to kill plants. The toxins produced by a group of fungi are known as mycoherbicides, and the toxins produced by microorganisms are termed as bio-herbicides (Jayaramiah et al. 2017). Most studies have focused on fungi compared to other different organisms. In some countries such as

Mexico, Argentina, Trinidad, and Cuba, the experts from International Institute of Biological Control carried out an extensive survey and ended up recording 26 species of fungi on *Parthenium*. The experts also realized some species preferable for biological control purposes, such as *P. melampodi* and *Entyloma compositarum*.

It was observed that the *Parthenium* was attacked by two kinds of bacteria, i.e. *Ralstonia solanacearum* and *Xanthomonas campestris*. These bacteria use roots as a route to infest plants. Apart from *Parthenium*, crops such as tomato, brinjal, and potato were also infested by *R. solanacearum*. It can survive as long as 6 months in the soil.

The occurrence of *Alternaria* sp. PMK2 was reported for the first time by Kaur and Aggarwal (2017). The species was chosen for an experiment to monitor the growth of *Parthenium* with the help of bio-control agents. Fortunately, the experiment proved to be worth as the results were encouraging. However, the assigned experts for this particular experiment could not justify the conclusion. At last, they settled the trial by assuming the cultural filtrate to be a toxic or homogenous substance. They stated that the contagious cultural filtrates require further studies to find the constituents present on them (Kaur and Aggarwal 2017).

Some kinds of pathogen have two sides (pathogen attacking both *Parthenium* and crops) (Kalidas 1981). The same pathogen used to control *P. hysterothorus* was also reported to harm or damage the crops. We can only conclude that until now none of the pathogens has demonstrated likely outcomes to diminish the effects of *P. hysterothorus* in the natural field conditions.

6.1.3 Control by insects

In Australia, *Zygogramma bicolorata* (leaf-feeding beetle), *Listronotus setosipennis* (stem-boring weevil), and *Epiblema strenuana* (stem-galling moth) were introduced to tackle *P. hysterothorus* (Dhileepan 2003). Numerous insects were identified on *P. hysterothorus*; however, not a single one of them had the potential of being host-specific.

Reports suggested that most of the insects on this weed in India are polyphagous pests of crops. A handful of it occurred in the significant portion which often led to the death of the plant, while many occurred in small part causing slight damage only (Sahrawat et al. 2018). *Z. bicolorata* (beetle) was imported into India in 1983 to control *P. hysterothorus* (Kaur and Aggarwal 2017). This beetle thrives till now in north, south, and central of India. The beetle, especially in large areas, has dramatically

aided in the combat against *P. hysterothorus*. The beetles also indirectly prevented the extinction of indigenous species which impeded the loss of biodiversity.

The adults defoliate the plants. When the beetles chew soft tissues beneath the flowers, the young buds are cut by the beetles. Defoliated plants begin to show dieback symptoms and eventually get killed (Sahrawat et al. 2018).

There are mainly four types of scale creepy crawlies that attack the stems and parts of the plant. Of them, *Parasaissetia nigra* and *Saissetia coffeae* are known to trigger the shrivelling of *Parthenium* plants in the glasshouse. Likewise, stems of the weed are attacked by *Orthezia insignis*. It forms dense colonies on the leaves and blossoms of the grass in summer, which ultimately brings about the withering of few plants (Sahrawat et al. 2018).

The larvae and adults species of bark beetle *Hypothenemus eruditus* and the larvae of *Oberea* sp. (beetle) swarm into the stems, which ultimately causes shrinking and death of the plants. The adults of some species such as flea beetle (*Luperomorpha vittata*) cause spots on the leaves by scratching the epidermis. They additionally benefited from stems by scratching the epidermis and scooping the cortex portion.

6.1.4 Control of *Parthenium* by allelopathic grass

Allelopathy is a biological phenomenon in which the organism generates biochemicals that can cause a damaging effect on the germination, growth, survival, and reproduction of plants and animals (Javaid et al. 2005). The allelochemicals such as flavonoids, terpenoids, and strigolactones can be used as herbicides, fungicides, and growth regulators. Many plants have been found to possess the ability to cause allelopathy (Hussain et al. 2011). Certain experiments were performed by the scientists to control the weeds.

Dichanthium annulatum, *C. pennisetiformis*, and *S. halepense* are the allelopathic grasses of which both the shoot and the root extracts decrease the germination and control the seedling growth of the tropical weed *P. hysterothorus* (Javaid et al. 2005). According to Javaid and Anjum (2006), the water extracts of *C. pennisetiformis* and *D. annulatum* were more inhibitory than those of *S. halepense*. The shoot extract of these plants hindered the growth and germination of *Parthenium* seedling more than the root extract.

Some plants such as *C. sericea*, *Croton bonplandianum*, *Mirabilis jalapa*, *C. tora*, *Sida spinosa*, *C. auriculata*, and

A. spinosus, which can cause allelopathy, ultimately smother the natural habitat of *Parthenium* (Wahab 2005). *C. sericea* was reported to minimize the assembly of *Parthenium* by 70% and its populace by 52.5% in India.

Similarly, the aqueous leaf concentrates of *Azadirachta indica*, *Eucalyptus tereticornis*, and *Aegle marmelos* completely hindered the germination of *Parthenium* seeds, and they may be used to control the weed (Kaur et al. 2014). The experts developed that the aqueous concentrates of the allelopathic grasses such as *Desmostachya bipinnata* and *I. cylindrica* not just smothered the germination and development of the *P. hysterophorus*, yet additionally limited the spread of the poisonous weed (Javaid et al. 2005). Therefore, *I. cylindrica* and *D. bipinnata* are used as a natural, effective product mainly to control the population of the noxious weed (*P. hysterophorus*) (Anjum et al. 2005).

In 1966, it was reported that *Xanthium strumarium* (wastelands weed) was able to compete with *P. hysterophorus* in India (Jayaramiah et al. 2017). It was reported that the watery shoot extracts of *Cassia occidentalis* have a remarkable effect on *P. hysterophorus* and gives an encouraging substitute to control it (Knox et al. 2010).

The aqueous extracts of *Tephrosia purpurea* (root, leaves, and stem) were tested under the laboratory conditions to measure its inhibitory potential on seedling growth and seed germination of *P. hysterophorus*. It was showed that the radicle was more suppressed than the plumule. It was also noticed that the inhibitory effect increases with an increase in the concentration of the aqueous extracts (Bhatnagar 2018).

In an attempt to impede the growth and germination of *P. hysterophorus*, the root and shoot extracts of three allelopathic plants, namely *Sorghum bicolor* L. (sorghum), *Helianthus annuus* L. (sunflower), and *Oryza sativa* L. (rice), were evaluated. After the experiment, it was concluded that there was no effect on seedling biomass and shoot length. However, the root length and germination were reduced by all the extracts (Javaid et al. 2006).

Researchers found out that the five allelopathic trees (leaves) such as *A. indica*, *Ficus benghalensis*, *Melia azedarach*, *Syzygium cumini*, and *Mangifera indica* can also control the noxious weed, *P. hysterophorus*. Out of these five allelopathic trees, *F. benghalensis* and *M. indica* were tested to be more inhibitory than the rest (Shafique et al. 2005).

In 2010, an experiment was performed to investigate the management of *P. hysterophorus* through watery bark and leaf extracts of *Alstonia scholaris*. It was reported that the watery leaf extracts of *A. scholaris* extensively reduced the seed germination of *P. hysterophorus* as compared to the bark extract. The growth

parameters such as shoot length, root length, and fresh biomass were also extensively reduced by all the leaf extract concentrations except 2% of leaf extract concentration (Javaid 2010).

A laboratory bioassay was conducted to investigate the effect of *Withania somnifera*, *Calotropis procera*, *Rumex dentatus*, and *C. occidentalis* on *P. hysterophorus*. Of the above four plants, the aqueous shoot extract of *Cassia* has a more significant potential to decrease the level of biochemical activities (protein content, chlorophyll, and nitrogen content) and increase the mortality, followed by *R. dentatus* (Knox et al. 2010).

Cassia uniflora belonging to Leguminosae family, a native of tropical America, was found in parts of Karnataka and has slowly spread to the neighbouring states of Karnataka. Young seedlings of *P. hysterophorus* are even smaller than those of *C. uniflora*. Additionally, *C. uniflora* has superior shoot and root systems. So, this feature equips them to defer flowering, minimize the number of capitula as well as seeds, and smother the vegetative growth of *P. hysterophorus* (Joshi 1991).

Furthermore, in 2017, Ramachandran studied the effect of aqueous leaf extract of *Datura metel* on noxious *P. hysterophorus*. In laboratory bioassay and foliar spray method, it was observed that the aqueous leaf extract of *D. metel* inhibited the seed germination and seedling growth and reduced the fresh weight of *P. hysterophorus*. Even the protein and the chlorophyll contents of the plants were reduced when the *P. hysterophorus* seedling was treated with a higher concentration of aqueous leaf extract of *D. metel*, which caused the death of plants. The plants treated with lower concentration of *D. metel* had enhanced protein and chlorophyll contents (Ramachandran 2017).

Bhatnagar (2018) reported the effect of aqueous extract (stem, root, and leaves) of *T. purpurea* on the germination and seedling development of *P. hysterophorus*. It was observed that the leaf extract of *T. purpurea* showed a more significant potential to inhibit the seedling and seed germination of *P. hysterophorus*. As compared to plumule, the radicle was inhibited more when the growth was observed in Petri plates. So, it was found that with the increase in aqueous extract concentration the inhibitory potential also increased (Table 2).

The allelopathic effect of sunflower on the germination and growth pattern of *P. hysterophorus* and *Amaranthus viridis* was intensively studied. It was noticed that sunflower aqueous extracts reacted differently with *Parthenium* and *Amaranthus*. All extracts suppressed the germination and growth parameters of *Parthenium* and *Amaranthus* in the concentrations of

50–100%. For example, sunflower leaves inhibited the germination and growth of *Parthenium* in a bioassay compared to *Amaranthus* (Shabbir et al. 2019). The leaf extracts manifested a more inhibitory potential than the stem and root extracts of the sunflower. Sunflower can be considered as one of the possible instruments to control the *Parthenium* in the near future.

6.2 Physical controls

Before flowering and seed set, the *Parthenium* can be removed manually. It has often been considered to be one of the most effective methods. *Parthenium* weed was successfully ploughed during the rosette stage before it produces seeds. Another way of mechanical control is the hand-weeding, which takes lots of time (Kalidas, 1981). Burning can also be considered to control the weed. However, this burning method has also been proved to be quite ineffective. It is so because, first, it consumes a vast quantity of fuel and other resources and it also damages the other productive plants growing in the locality (Ray and Gour 2012).

6.3 Chemical controls

Chemical control comes into the scene when the natural enemies of *Parthenium* are absent. The most popular and effective chemical herbicides are glyphosate, bromoxynil, chlorimuron-ethyl, ametryn, bromoxynil + 2-methyl-4-chlorophenoxy acetic acid, atrazine, and metsulfuron

(Javaid and Anjum 2006). In the areas such as barren land, along railway tracks, roadsides, and water channels, it was reported that the weed could effectively be controlled at the rosette stage. Among all the methods, spraying the solution of common salt at 15–20% to manage *P. hysterophorus* has been considered to be the easiest way (Jayaramiah et al. 2017).

Though glyphosate and isoproturon are both effective in eliminating *P. hysterophorus*, glyphosate is better than isoproturon (Shabbir 2014). Extensive chemical utilization has escalated the user's concern in the present years. Furthermore, the toxic effects such as carcinogenicity, residual toxicity problems, and environmental pollution have put a limit to its utilization (Javaid 2010).

6.4 Integrated management of weed

There should always be more than one approach to minimize *P. hysterophorus* successfully. Some of the strategies such as biological, mechanical, and chemical methods can be combined to regularly monitor the weeds and make sure that their amount did not exceed the minimum threshold level (Jayaramiah et al. 2017). The integrated management of *Parthenium* is a technique to manage weeds with the help of different technologies. Under the given agro-ecosystem, it aims to improve the productivity of the crop at a minimal cost possible and to consider ecological and socioeconomic constraints (Kumar 2016).

The integrated weed management technique was implemented in Australia complementary to biological

Figure 2: Representation of the overall harmful effects of *P. hysterophorus* and its control measures.

Table 1: Different chemical constituents of *P. hysterophorus*

S. no.	Main compounds	Constituents	References
1	Amino acids	Glycine, proline, alanine, and lysine	Roy and Shaik (2013)
2	Essential oils	<i>p</i> -Cymene, tricyclene, bornyl acetate, α -pinene, β -pinene, α -thujene, β -elemene, camphene, tetradecane, oxo- α -ylangene, dodecane, α -phellandrene, benzothiazole, α -terpinene, nerol, γ -terpinene, α -humulene, and sesquiterpenes	Patel (2011); Roy and Shaik (2013)
3	Terpenoids	Sesquiterpene lactones: ferulic acid, parthenin, epoxyartemisin, quercetagenin, caffeic acid, <i>p</i> -hydroxybenzoic acid, cornopolin, balchanin, costunolide, <i>p</i> -anisic acid, and artemisinin	Roy and Shaik (2013)
4	Flavonoids	Luteolin, jaceidin, quercetagenin, 3,7-dimethyl ether, apigenin, santin, 6-hydroxyl kaempferol, quercetin, chrysoeriol, and centaureidin	Patel (2011); Roy and Shaik (2013)
5	Allelochemicals or phytotoxic compounds	Hysterin and ambrosin, hymenin, fumaric acid, vanillic acid, chlorogenic acid, anisic acid, gallic acid, and <i>p</i> -coumaric acid	Patel (2011)
6	Other compounds	Canin, parthenolide, reynosin, santamarine, tannins, pyrethrin, hysteron, etc.	Roy and Shaik (2013)

Table 2: List of allelopathic plants used for suppressing the growth and germination of the weed (*P. hysterophorus*)

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

control technique with other management techniques to control leaf *P. hysterophorus*, where the suppressive plants such as *Astrelba squarrosa* and the introduced legume, butterfly pea (*Clitoria ternatea*), along with two biological control agents, *Z. bicolorata* and *E. strenuana*, were used. It successfully suppressed the weed in the absence of biological control agents (Ray and Gour 2012). Additionally, its potential to suppress could be increased when one of the aforementioned biological agents is present. These profound experiments proved that the best way to control weed is to

complement by biological control techniques with suppressive plants (Kaur et al. 2014).

7 Conclusion

P. hysterophorus is a flowering plant which belongs to the Asteraceae family. It is commonly known as congress grass, carrot weed, and broom bush in India. *P. hysterophorus*

has been figured out as a significant threat and acts as a barrier for crop production, although farmers also put great efforts to eliminate the congress grass to get better yield (Figure 2). *P. hysterophorus* decreases the stability of an improved grazing land establishment, which also reduces pasture production. *P. hysterophorus* is viewed as an unsafe weed all around the world, including India. All the information reflected in this review suggested that there may be the possibility of health hazards due to *P. hysterophorus*, especially in the urban residents of India and Australia. Furthermore, this review emphasizes the effects of *P. hysterophorus* on agricultural and natural ecosystems. Distinct specialists around the world have decided to focus on weed management strategies due to its rapid growth.

Some of the allelopathic plants have a tremendous ability to control weed in problematic urban places. One such plant is marigold, which is highly traditional and abundant in the Indian market. Marigold can be used in urban places where it can mitigate the weed growth. It is an appreciatively marketable product having a high aesthetic value. In Bangalore, a booming city in India, *Zygogramma* beetle has produced a remarkable result in eliminating *P. hysterophorus*.

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