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REVIEW ARTICLE

AN UPDATED REVIEW ON THE HARMFUL AND BENEFICIAL EFFECTS OF *PARTHENIUM HYSTEROPHORUS* L.

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Abstract : *Parthenium hysterophorus* is an annual ephemeral weed belonging to the Asteraceae family. It is highly pernicious to humans, animals, plants and the environment. It has the potential to invade and take over a large area over a very short time through allelopathy. Presently, parthenium weed is among the ten worst most hazardous and devastating weeds of the world. In Malaysia, the weed is gradually becoming a serious threat to humans, domestic animals and the ecosystem. However, research findings over the years have proven that apart from the deleterious effects, it has some potential that can be utilized for medical, agricultural and industrial uses. To fully evaluate the potential of this weed for human use, a complete knowledge on its beneficial and harmful effects most be known. This review is an effort to update the current knowledge on the harmful and beneficial effects of the weed on humans, animals, plants and the environment.

Key words : Parthenium, Distribution, Allelochemicals, Effects.

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1. Introduction

Parthenium hysterophorus L. is an annual ephemeral herb belonging to the Asteraceae family, commonly called congress grass, carrot weed, white top, broom weed, Santa maria fever few etc. [Jayaramaiah *et al*. (2017)]. It is also known with many vernacular names such as chatak chandami and gajar gas safe topi [Nigatu *et al*. (2010), Kushwaha and Maurya (2012)]. The weed is reported to be among the ten most terrible weeds known globally and has been documented in the database of invasive species [Aneja *et al*. (1991), Bhateria *et al* (2015)]. Parthenium is labeled by many researchers as a gravious weed of pasture, uncultivated lands and agricultural fields in the world [Tomado and Milberg (2002), Kushwaha and Maurya (2012)]. It is a highly prolific and pernicious weed that is highly acclimatize and can grow everywhere, invades all types of pasture land and caused serious decline in crop yield [Aneja *et al*. (1991), Saini *et al*. (2014)]. *Parthenium hysterophorus* is also a weed that has serious health hazards [Dhawan and Dhawan (1995), Pandey (2009)]. On the other hand, the weed through recent research findings, it has shown to possess very useful biological activities in animal and human models as well as in the natural environment [Pandey (2009)]. The current review is to provide an update on the harmful and beneficial effects of *P. hysterophorus* by critically analyzing the results of published research works as well as unpublished works on the biology and economic importance of this weed.

1.1 Origin and Distribution

Parthenium hysterophorus is considered as one of the worst most invasive species, reported to have originated from Northeast Mexico through hybridization

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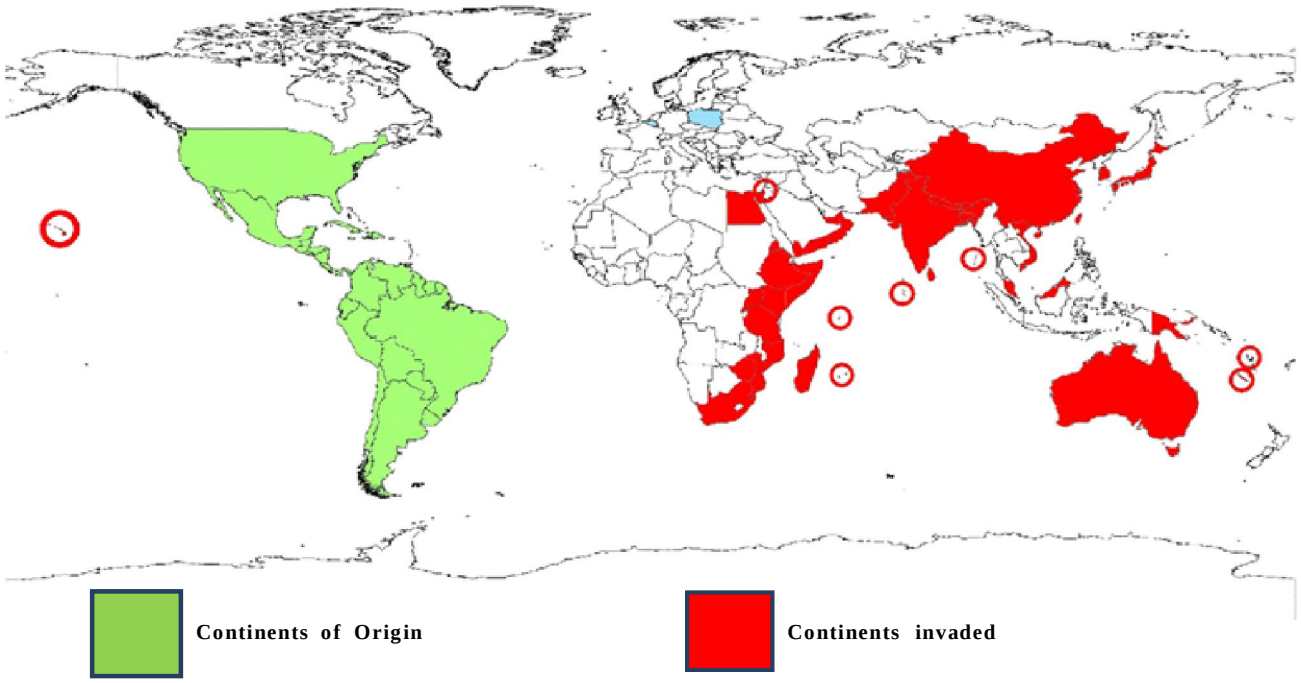

Fig. 1 : Global distribution of *P. hysterophorus* [EPPO (2014)].

between *Parthenium confertum* and *Parthenium bipinnatum* [Saini *et al*. (2014), Kushwaha and Maurya (2012)]. In the last 100 years, it has spread to other continents such as Asia, Australia and Africa [McConnachie *et al*. (2010)]. The weed was reported to have invaded the United States of America, West Indies, India, Nepal, Malaysia, Pakistan, Africa, China, Vietnam and Australia [Kushwaha and Maurya (2012), Karim (2014a,b)].

On the Asian continent, *P. hysterophorus* has been reported as a weed of public concern in India [Sharma and Tyagi (1979)], Nepal [Aneja *et al*. (1991), EPPO (2014)], Bangladesh [Mahadevappa (1997), EEPO (2014)], China [Aneja *et al*. (1991), EPPO (2014)], Japan [EPPO (2014)], Sri Lanka [EPPO (2014)], Vietnam [Aneja *et al*. (1991), EPPO (2014)] and Malaysia [Karim (2014a)].

In Africa, *P. hysterophorus* has been reported to be found in south Africa [Navie *et al*. (1998), McConnachie *et al*. (2010), EPPO (2014)], Ethiopia [Fessehie *et al*. (2005), Tamado and Milberg (2000), EPPO (2014)], Eritrea [USDA-ARS (2012), EPPO (2014)], Swaziland [MacDonald *et al*. (2003), EPPO (2014)], Mozambique [Wild and Barbosa (1967), Aneje *et al*. (1991), EPPO (2014)], Kenya [Navie *et al*. (1998), EPPO (2014)], Tanzania, Uganda, Zimbabwe [McConnachie *et al*. (2010), EPPO (2014)], Egypt [Zahran and Willis (2009), EPPO (2014)], Madagascar [Aneje *et al*. (1991), EPPO (2014)], Somalia [Tamado and Milberg (2000), EPPO (2014)] and Comoros island [Missouri Botanical Garden (2008), EPPO (2014)].

In North America, which is native to the weed is found widespread in Mexico and USA though not invasive [Holm *et al*. (1991), Aneja *et al*. (1991), EPPO (2014)]. While in central America and the Caribbean, parthenium is native to most of the countries except in Cuba and Calcos Islands where it has been introduced [GBIF (2008), EPPO (2014)]. In Oceania, parthenium is present in Australia [Holm *et al*. (1991), EPPO (2014)] and Papua New Guinea [EPPO (2014)] (Fig. 1).

The widespread distribution in many countries of the world is attributed to the presence of allelochemicals present in the plants which gives them the invasive capacity and allopathic effects to disrupt natural ecosystems [McConnachie *et al*. (2010) and Evans (1997)]. The allelochemicals impede on seed germination and plant growth particularly of neighboring crop plants such as cereals, vegetables, grasses and leguminous plants [Evans (1997), McConnachie *et al*. (2010)], thereby resulting in the displacement of indigenous species of plants, thereby modifying grasslands to open woodlands, river banks and flood plains to sole crop shrub lands [McFadyn (1992), Chippandale and Penetha (1994)].

1.2 Habitat

Parthenium hysterophorus inhabits different tropical ecosystems of the world. The weed is found distributed in vegetation along shores of rivers (riparian vegetation), road sides, along railways and in savanna grasslands, plain forestlands, uncultivated lands, disturbed sites [Karim (2014a)], small gardens [Mamoud *et al*. (2015)], residential areas, recreational areas, industrial areas, play grounds, seasonal flood plains and river banks [Kilewa and Rashid (2014), Bhateria *et al.*(2015)]. It is exceptionally combative in deteriorated or disturb meadowlands in desert liked climes. It is a draught resistant plant that can grow on all types of soils **[**Gnanavel and Natarajan (2013)**]**. However, it is most abundant in alkaline and clay loam soils [Kuar *et al*. (2014)].

1.3 Nomenclature

Parthenium weed is scientifically known as *Parthenium hysterophorus* L. and also known internationally in English as barley flower, bastard feverfew, broomweed, congress grass, grass weed, Santa Maria feverfew and whiteheads. In Spanish, it is referred to as ajenjo Cimarron, amargosa, camalote, amargosa, Istafiate, reqeson etc. In French and Portuguese, it is called parthenium matricaire and Mentruz, respectively [EPPO (2014)].

Depending on the countries where it is found, parthenium has different local names. For instance, in India, parthenium is locally called congress grass, carrot weed, bitter weed, gajar ghas, broom grass, safed topi etc [Kaur *et al.*(2014) and Bhateria *et al.* (2015)]. In Brazil, it is known as Coentro-do-mato, fazendeino or losna-branca, while in Cuba it is called Cotitillo. In Jamaica the weed is called white top [EPPO (2014)]. Parthenium is locally known as baby flower, Gandhi booti, lewanai bhang in Pakistan, whereas in USA it is false ragweed, ragweed parthenium **[**EPPO (2014)]. Recently, the weed has been identified in Malaysia where it is locally called Rumpai Miang Mexico [Karim (2014b)].

1.4 Botanical description

Parthenium hysterophorus is a seasonal short-lived herb (alternatively under some circumstances, an ephemeral) perennial having an upright and many offshoots. The plant exhibits two distinguishable phases in life cycle, namely the vegetative or juvenile and the reproductive or adult stage.Matured plants usually attend a height of 2.5 m; though maximum numbers of the weeds do not surpass 1.5 m. Leaves are puberulent and vigorously divided into smaller lobes. Small white flowers having 4 mm transversely possess five to eight different beams of small flowers, which grow on the tip of the shoot. A normal flower bears 4-5 achenes black in colour (2 mm) encircled in an amber-coloured fruit sheet having two laterally affixed infertile florescence. Flowering occurs four to eight from the time of germination and persist up to unfavourable growth conditions (drought and frost) kills it. Two to three life cycles can be completed when conditions are favourable [Fatimah and Ahmad (2009)]. The plant can produce many seeds, on average 15,000 seeds and matured huge plants are reported to produce up to 100,000 seeds [Kushwaha and Maurya (2012), Nigatu *et al.* (2010), Bhateria *et al*. (2015), Meena *et al*. (2017)]**.** *Parthenium hysterophorus* suppress neighboring vegetation because of its ability to germinate rapidly, grow very fast and the allelopathic stuff, which allow it to thrive and bear enormous amount of seeds contributing to the increased magnitude of its seed bank in the ground [Nguyen *et al*. (2017)].

1.5 Seed dissemination and germination

Parthenium hysterophorus seed are substantially disseminated via different means, which include water currents, animals, vehicles, machinery, grains, stock feed and to a lesser extent by the wind. Long distance dispersals is via vehicles, farm machinery and flooding. The rapid distribution of seeds coupled with their capacity to stay viable in the ground for numerous years creates one of the most complicated challenges for elimination [Kaur *et al*. (2014)]. The seeds lacks dormancy period; therefore the seeds can germinate whenever moisture is obtainable. Seeds germinate at the onset monsoon and flowering begins a month later and last up to three months [Kushwaha and Maurya (2012)].

2. Harmful Effects

Parthenium hysterophorus is viewed as one of the most perilous earth bound weeds due to its damaging effects to humans, animals, the environment as well as other life forms (Table 1), which are discuss in details as follows:

2.1 Effects of parthenium on human health.

Parthenium have been reported by many

researchers to be responsible for many human health problems when exposed to the weed for a long time, long time exposure may cause dermatitis, asthma, bronchitis and hay fever [Kologi *et al*. (1997), Pandey (2009) and Khaket *et al*. (2015)]. Studies carried out in Jijiga (Ethiopia) suggested that parthenium induces asthma, bronchitis, dermatitis and hay fever in human [Abdulkarim-Ute and Legesse (2016)]. A survey in Queensland, Australia showed that 10% of workers in parthenium plagued areas had manifested apparent allergic symptoms to the weed [Bhateria *et al.* (2015)]. Karim *et al*. (2017) also recorded allergic reaction on the hands of farmers in areas invaded by parthenium weed in Malaysia. These are attributed to the presence of chemical allegens present in the plant which include parthenin, coronopilin, tetraneurin-A and ambrosin [Meena *et al*. (2017) and Pandey (2009)].

2.2 Human dermatitis

Farmers, who are exposed to *P. hysterophorus* over a long time (1-10 years) developed contact skin dermatitis also known as allergenic eczematous contact dermatitis (AECD) [McFadyen (1992)]. Pandey (2009) reported that the dermatitis may appear in various patterns. He further stated that a typical airborne contact dermatitis may involve eyelids, the nose and upper lips, areas under the chin, and behind the ears, atopic eczema, cirrhotic amenorrhoea, flake eczema and light receptive amenorrhea. Regular exposure to *P. hysterophorus* resulted in dermatitis in about 15% of individuals in a population [McFadyen (1992), Khaket *et al*. (2015)].

Parthenium dermatitis was classified by some authors based on the clinical signs and symptoms. Bhateria *et al*. (2015) classified parthenium dermatitis into three different types as follows :

1. The classical pattern also referred to as Air Borne Contact Dermatitis (ABCD). This invades the face, particularly the eyelids and/or neck region, V shape of breast region, parallelepiped as well as the knee pit.
2. The Chronic Actinic Dermatitis (CAD) this fashion invades all unprotected regions like the eyebrow, cheeks, rim of ears, backside of collar, abaxial of limbs hands as lichenified inflammation, boils having equal sparing of non-sun reveal regions of the eyelashes, behind the auricles of the ear and underside of jaw and skinfolds.
3. The mixed pattern (mixture of ABCD and CAD patterns) is characterized by widespread permeated scabrous boils over the body surfaces that are not covered and there is dermatitis of the eyelashes, pliancy of extremities and the throat region.

However, Meena *et al*. (2017) further classified parthenium dermatitis into five types *viz*:

1. The classical pattern popularly known as airborne atopic eczema and invade the brow, particularly eyelashes as well as the neck region, V of the upper trunk, antecubital and popliteal fossae.
2. The chronic actinic dermatitis (CAD), this affect the unprotected areas like the brow, ears, cheeks, nape of neck, abaxial of limbs, and phalanges as erythematous boils, speckles, or pimple bump with similar scrimping of non-sun show portions like the eyelashes, retro auricular portions and underside of jaw as well as the profundity of the skin folds.
3. The mixed pattern is a consolidation of two patterns *i.e*. the classical and CAD. This pattern is characterized by randomly permeated scaly swellings over the visible body sections as well as eczema over eyelashes, curved parts and throat region.
4. The light receptive erythematous ebullition models show severe itching, unconnected, uniform, purple boils and plaques over areas exposed to sunlight like the brow, ears, face, breast and rear extensor looks of arms and back side of hands initiating photosensitive lichenoid explosion.
5. The *Prurigo nodularis,*this model is presented as numerous hyperkeratotic inflammation and protuberances through extreme having characteristic histopathological aspect resembling *P. nodularis* [Aneja *et al.*(1991), Sharma *et al*. (2013)].

Farmers are disturbed about *P. hysterophorus* impacting on food and fodder crops, as its pollen and dust evoke allergenic contact eczema in humans [Morin *et al*. (2009)].

2.3 Ashtma

Inhalation of the pollens of parthenium elicits allergenic rhinitis, which develops into bronchitis or asthma if the pollens are inhaled into the respiratory tract during breathing [Towers and Subba Rao (1992)].

Regular exposure to parthenium resulted in 7-15%

Table 1 : Harmful Effect of *Parthenium hysterophorus*.

Harmful effects	Reference
On humans	
Human dermatitis	McFadyen (1992), Evans (1997), Pandey (2009), Morin *et al*. (2009), Bhateria (2015), Meena *et al* (2017).
Ashma	Towers and Sabba Rao (1992), McFadyen (1992), Evans (1997), Khaket *et al*. (2015)
Hay fever	Rao *et al*. (1985), Towers *et al*. (1977), Srinamarao *et al*. (1993), Khaket *et al*. (2015).
Allergic bronchitis	Kologi *et al*. (1997)
Black spots over skin and around eyes	Maishi *et al*. (1998)
On animals	
Livestock dermatitis	Qureshi *et al*. (1980), Ahmed *et al*. (1988)
Tainting of milk	Towers and Sabba Rao (1992), Ayele (2007)
Tainting of meat	Tudor *et al*. (1982).
Death of animals	Pandey (2009), Oudhia (1998), Narasinham *et al*. (1993)
On the ecosystem	
Habitat change and biodiversity loss	Ayana (2011), Dalip (2013), Meena *et al*. (2017)
On agriculture	
Inhibit the growth of nitrogen fixing bacteria	Lalita and Kumar (2018)
Inhibit seed germination through allelopathy	Gunaseelan (1998), Singh *et al*. (2003), Maharjan *et al*. (2007), Meena *et al*. (2017)
Crop yield decline	Khosla and Sobti (1981), Narasimhan *et al*. (1984), Mcfadyen (1992)

of the population developing respiratory problems [McFadyen (1992), Khaket *et al*. (2015)]. The respiratory problems generally start with high fever and after 3-5 years of gradual exposure, respiratory problems become more severe resulting into asthma and allergic bronchitis [Evans (1997), Khaket *et al*. (2015)].

2.4 Hay fever

Parthenium weed's pollens in the air cause induction of allergic rhinitis also called hay fever [Rao *et al*. (1985), Khaket *et al*.(2015)]. According to a survey carried out in parthenium infested areas in India, it was reported that, 44% of the total pollen load was composed of parthenium pollen from June to September, 1980 [Seetharamiah *et al*. (1981), Khaket *et al*. (2015)]. The inhalation of pollens through breathing can elicit allergenic rhinitis and speed up the evolution of bronchitis or asthma [Evans (1997), Khaket *et al*. (2015)]. Contact of the nasal mucous membranes with high molecular weight chemicals like proteins of plant pollen may cause allergic rhinitis (hay fever) [Towers *et al*. (1977), Sriramarao *et al*. (1993), Pandey (2009)].

Evans (1997) reported that air pollen sampling in Bangalore (Southern India) over a six year time frame showed that 40-60% of the total pollen count are from parthenium, which made them to conclude that parthenium pollen was the main cause of allergic rhinitis in that city with 7% of the people affected and over 40% susceptible to the pollen.

2.5 Effect on animals

The whole parthenium plant is lethal to humans and animals because of chemical substances found in the plant [Singh *et al*. (2003), Abdulkerim-Ute and Legesse (2015)]. The lethal effect was attributed largely to a chemical substance in the plant known as 'parthenin' and diverser phenolic acids like caffeic acid, vanillic acid, anisic acid, p-anisic acid, chlorogenic acid and parahydroxy benzoic acid which are deadly to human beings and animals [Mahadevappa (1997), Oudhia (1998) and Bhateria *et al*. (2015)].

Grazing of animals in areas that are highly infested with parthenium or due to unintended or determined grazing on it results in the animals developing many symptoms of acute toxicity, which if not addressed in time may even result in the death of the animals. Pandey (2009) reported that ingestion of parthenin through feeding on parthenium plants in cattle, buffaloes and other animals may cause illness or death. Grazing of animals such as buffaloes and goats in areas infested by this weed in India often results in bitter milk problem [Picman (1986), Pandey (2009)]. If parthenium is ingested by animals, it is accountable for mouth ulceration with enormous salivating. Substantial quantity (10-50%) of the weed when consumed by cattle can result in their death [Bhateria *et al*. (2015)].

Similarly, it causes emaciation, itching, hair fall, diarrhoea and eye irritationin dogs. Parthenium also caused acute illness when it was mixed with cattle fodder [Aneja *et al.*(1991), Bhateria *et al*. (2015)]. Continuous feeding of aerial parts of *P. hysterophorus* up to 12 weeks cause anorexic and dermatitis in adult nanny goats-Osmanabadi [Ahmed *et al*. (1988)]. The meat was tainted in sheep fed on a diet having 30% *P. hysterophorus* [Abdulkarim-Ute and Legesse (2016)]. Tainting of milk was also reported in cows fed on *P. hysterophorus* [Towers and Rao (1992), Khaket *et al*. (2015)]. In pastures, the weed can put the livestock at risk, lower their productivity by reducing the quality and quantity of forage [Klingman and Ashton (1982)] and also affects health, milk and meat quality of grazing animals [Evans (1997)]. Animal feed stuff contaminated with parthenium when fed to animal's leads to polluted milk and the hepatotoxic parthenin in tainted milk reacts synchronously with copper, evoking Childhood Cirrhosis [Tanner and Mattocks (1987)].

2.6 Effects on biodiversity

Parthenium has invaded many countries of the world because of its invasive capacity and allelopathic potentials. It has been reported to because of a total habitat change in native Australian grasslands, open woodlands, river banks and flood plains [Lakshmi and Srinivas (2007), Meena *et al*. (2017)]. The report of Dalip *et al*. (2013) from Mehari Sub-Watershed of Rajouri Forest Range, India, indicated that parthenium weed occupy new surroundings and often substitute the native plant species, resulting in a serious damage to biodiversity. A study by Ayana and Teshome (2011) reported that *P. hysterophous* caused about 60% decline in stand density of herbaceous species in Awash National Park (Ethiopia) within a few years from its introduction. Similarly, Asresie *et al*. (2008) pointed out that there is an increase in the level of parthenium infestation caused rapid decline in the population and diversity of indigenous species in the ecosystem. Parthenium can produce on average, 624 million of pollen grains per plant which are dispersed in clusters of 600-800 grams.

2.7 Effects on crops

Parthenium plant contains chemicals, like parthenin, hysterin, hymenin and ambrosin. As a result of the presence of these chemical compounds, it wields powerful allelopathic action on varieties of crops. Parthenin was found to be responsible for the inhibition of seed germination as well as radicle growth in a variety of dicotyledonous and monocotyledonous plants [Gunaseelan (1998), Meena *et al*. (2017)]. The weed interferes with nodule formation in legumes due to prevention of the action of nitrogen fixing and nitrifying bacteria, such as *Rhizobium*, *Actinomycetes*, *Azotobacter* and *Azospirillum* [Lalita and Kumar (2018)].

Parthenium can produce on average, 624 million of pollen grains per plant, which are dispersed in a bunch of 600-800 grains. The pollen grains are deposited on the vegetative and blooming parts, as well as the surfaces of the stigma of surrounding plants or crops, resulting in the prevention of fruit formation in crops such as tomato, brinjal, cowpeas, capsicum species and maize. In India, the weed was reported to be responsible for decline in yield of up to 40% in agricultural crops and 90% recession in carrying capacity of pasture [Saini *et al*. (2014)]. In Ethiopia 97% of grain yield loss in sorghum was reported in parthenium infested fields left uncontrolled for the whole farming season [Narasimhan *et al*. (1984), Mcfadyen (1992)]. In Australia, 170000 km^2 of prime grazing country in Queensland invaded by *P. hysterophorus* resulted in economic losses of around $16.8 million per annum to the pasture industry [Tefera (2002)]. Carrying capacity of farms invaded by parthenium was reduced by 40% on cracking clay soils having annual rainfall between 600 and 800 mm [Pandey (2009), Urmilesh *et al*. (2011)]. The weed also serves an alternate host for many diseases caused by viruses in crop plants [Kumar *et al*. (2016)].

Table 2 : Beneficial effects of *Parthenium hysterophorus*.

Beneficial effects	**Reference**
Medical/Health benefits	
Traditional or folk medicine for the treatment of headache, diarrhea, fever, skin rashes, herpes, toothache, gynecological problems	Raghu *et al*. (2014), Bagchi *et al*. (2016), Getachew (2017), Meena *et al*. (2017).
Anti-diabetic activity	Arya *et al*. (2012), Raghu *et al*. (2014), Khaket *et al*. (2015), Bagchi *et al*. (2016), Getachew (2017).
Thrombolytic activity	Al-Mamun *et al.* (2010)
Antioxidant activity	Raghu *et al*. (2014), Khaket *et al*. (2015), Bagchi *et al*. (2016).
Anti-tumor/Anti-cancer activity	Das *et al*. (2007), Haq *et al*. (2011), Raghu *et al*. (2014), Bagchi *et al*. (2016), Khaket *et al*. (2015).
Anti-inflammatory activity	Pandey *et al.* (2012), Raghu *et al*. (2014), Bagchi *et al*. (2016)
Wound healing activity	Kumar *(*2012)
Antimalarial	The wealth of India (2003), Kumari *et al*. (2016).
Antimicrobial	
Antifungal	Rai and Upadhyay (1990), Rao *et al.* (1985), Rukhsana *et al*. (2003), Harsha *et al*. (2011), Harsha *et al*. (2011), Rahmat *et al*. (2011), Naina and Archana (2012), Manimegalai and Ambikapathy (2012), Shazia and Sobiya (2012), Zunera *et al*. (2012), Gaurov *et al*. (2013), Malarkodi and Manoharan (2013), Ajay *et al*. (2013).
Antibacterial	Chopra (1960), Dikshit and Dixit (1982), Harsha *et al*. (2011), Hina *et al*. (2011), Barsagade and Wagh (2010), Siddhardha *et al*. (2012), Harsha *et al*. (2011), Malarkodi and Manoharan (2013), Ajay *et al.* (2013), Rahmat *et al*. (2011), Sukanya *et al*. (2009).
Antiamoebic	Sharma and Bhutani (1988), Raghu *et al*. (2014), Bagchi *et al*. (2016), Meena *et al*. (2017), Getachew (2017).
Larvicidal	Ahmad *et al*. (2011), Khan *et al*. (2014), Amir *et al*. (2017).
Trypanocidal	Talakal *et al*.(1995)
Agricultural importance	
Bioherbicidal activity	Khosla *et al*. (1980), Khosla and Sobti (1981), Kumari (1990), Singh *et al*. (1992), Pandey (1996), Batish *et al*. (1997), Acharya and Rahman (1997), Marhajan *et al*. (2007), Nigatu *et al*. (2010).
Insecticidal activity	Tilak (1977), Picman *et al*. (1981), Gajendran and Gopalan (1982), Fagoonee (1983), Dhandapani *et al*. (1985), Datta and Saxena (2001), Sohal *et al*. (2002).
Nematicidal	Rajendran and Gopalan (1980), Gommers (1973), Hassan and Jain (1984), De la Fuente *et al*. (2000).
Compost as green manure	Kishor *et al*. (2010), Khan *et al*. (2011), Channappagoudar *et al*. (2007), Kishor *et al*. (2010), Getachew (2017).
Formulation of animal feed Biochar production	Narasimhan *et al*. (1993), Mane *et al*. (1986), Patel (2011), Kumar *et al*. (2013), Saini *et al*. (2014)
Industrial uses.	
As additive in cattle manure for biogas production	Gunaseelan (1998), Patel (2011).
Use as substrate for commercial enzyme production	Dwivedi *et al*. (2009).
Removal of heavy metals and dyes.	Ajmal *et al*. (2006), Singh *et al*. (2008), Patel (2011), Khaket *et al*. (2015)
Paper and Pulp production	Shubhaneel *et al*. (2013), Saini *et al.* (2014).

3. Beneficial effects of Parthenium

Parthenium is not only an invasive weed but also shown to have beneficial effects which are discussed in Table 2.

3.1 Traditional Medicine

Parthenium hysterophorus has been reported to be used in traditional medicine by different groups of people in places where the weed is found. In the Caribbean and central America, it has been used by the indigenous people in the treatment of diseases such as fever, diarrhoea, urinary tract infection, dysentery and malaria [Navie *et al*. (1996), Getachew (2017), Meena *et al*. (2017)]. Ethnobotanically, it is also reported to be utilised by some tribes as a remedy for boils, bumps, eczema, herpes, rheumatic pain, cold, heart trouble, migraine, headache, toothache, stomach aches and gynaecological problems [Raghu *et al*. (2014), Getachew (2017)]. The bioactive compounds in the plant are sesquiterpenes, lactones, flavonoids, glycosides and pinines which are responsible for the curative potentials [Raghu *et al*. (2014), Bagchi *et al*. (2016)].

3.2 Anti-diabetic/ Glycemic activity

Parthenium has been reported to possess anti-diabetic potentials particularly type II diabetics. Aqueous extracts of the plant were found to exhibit significant glycemic activity in alloxan induced diabetics in rats where the fasting blood glucose level dropped [Petel *et al*. (2011), Khan *et al*. (2014), Khaket *et al*. (2015), Arya *et al*. (2012), Raghu *et al*. (2014), Bagchi *et al*. (2016), Sahrawat *et al*. (2018)]. The flower extract of parthenium can be utilise for the development of drugs for diabetes mellitus [Getachew (2017)].

3.3 Thrombolytic activity

Coronary heart disease has been responsible for many deaths worldwide, as such there are frantic efforts put in place to research into compounds that will delay the process of thrombus by the usage of clot dissolving agents. A lot of plants have been evaluated for thrombolytic activity of which parthenium have been reported to demonstrate significant thrombolytic effect comparable to standard thrombolytic agent, streptokinase. Crude methanolic extract of *P. hysterophorus* has been reported to show significant thrombolytic effect comparable to standard thrombolytic agent, streptokinase [Al-Mamun *et al*. (2010)]. Parthenolide and some other metabolites were determined as the inhibitor of human blood platelet function [Hewlett *et al*. (1996)]. The thrombolytic activity is a possible relevant effect to migraine prophylaxis through the inhibition of serotonin releasing from platelet by platelet aggregating agents: adenosine diphosphate, adrenaline, sodium arachidonate, collagen, and U46619 [Hewlett *et al*. (1996)].

3.4 Antioxidant Activity

Antioxidant phytochemicals protect the cells from oxidative damage caused by free radicals [Raghu *et al*. (2014), Bagchi *et al*. (2016)]. Free radicals are considered to be agents for many diseases also attack DNA and cause mutation leading to cancer [Ahmad *et al*. (2010)]. Synthetic antioxidants are reported to be carcinogenic hence restrictions on their use [Ames *et al*. (1993)]. As a consequence attention of scientist is geared towards research for natural antioxidants. Parthenium has been reported to be a good source of natural antioxidants because of its high antioxidant activity. DPPH (2, 2-diphenyl-1- picrylhydrazyl radical) scavenging assay revealed that Methanolic, ethanolic and acetone extract of *P.hysterophorus* showed antioxidant activity [Ahmad *et al*. (2010), Raghu *et al*. (2014), Bagchi *et al*. (2016), Khaket *et al*. (2015)]. Based on the published information, parthenium can be an active potential source of natural antioxidant, which can be produced in commercial quantities [Khaket *et al*. (2015)].

3.5 Anti-tumor

Researchers have demonstrated that *P. hysterophorus* have anti-cancer activity and thus have the potentials for the treatment of tumors. The methanolic flower extract of the plant exhibited anti-tumor effects in host mice bearing transplantable lymphocytic leukemia [Mukherjee and Chatterjee (1993), Khaket *et al*. (2015)]. The level of neoplastic markers like glutathione, cytochrome P-450, glutathione transferase and UDP-glucuronyl transferase altered substantial thereby slowing down the development of the tumors and increase survival [Mukherjee and Chatterjee (1993), Khaket *et al*. (2015)]. Methanol, ethanol, chloroform and aqueous extracts of *P. hysterophorus* parts were all found to be significantly cytotoxic to the investigated human cancerous cell live ovary (IGROVI), lung (A-549), prostrate (PC-3), breast (MCF- 7) and CNS (SF-295) except Lung cancerous cell line (Hop-63) [Haq *et al*. (2011), Raghu *et al*.

(2014), Bagchi *et al*. (2016)]**.** Parthenin exhibited significant anticancer property, when the parthenin and the constituents was evaluated using Jurkat (human: T lymphocyte; acute T cell leukemia), HL-60 (human leukemia) and Hela (human cervical carcinoma) cells [Das *et al*. (2007)].

3.6 Anti-inflammatory activity

Parthenium hysterophorus extracts were found to have anti-inflammatory potentials when trials were conducted on mice and rats. Administration of 10, 20, 40mg/kg of body weight against acetic acid induced edema in mice and carrageenan induced paw edema in rats showed significant anti-nociceptive and anti-inflammatory effects, respectively [Raghu *et al*. (2014), Bagchi *et al*. (2016)]. In a related trial, when 200mg/ kg of body weight of fresh leaves ethanolic extracts exhibited high degree of anti-inflammatory effect in carrageenan induced paw edema in rats [Pandey *et al*. (2012), Raghu *et al*. (2014), Bagchi *et al*. (2016)]. The anti-inflammatory property of the plant was suggested to be an inhibitor of cellular phosphate which prevents the release of arachidonic acid in response to appropriate physiological stimuli [Raghu *et al*. (2014), Bagchi *et al*. (2016), Sahrawat *et al*. (2018)].

3.7 Wound healing activity

Externally leaf paste application of *P. hysterophorus* showed wound healing activity [Kumar (2012)].

3.8 Antimalarial Activity

Extracts of *P. hysterophorus* were evaluated for antimalarial potentials, the findings of the studies showed that the plant has compound that showed positive antimalarial activity. Methanol extract of the leaves exhibited good *in-vitro* antiplasmodial activity against chloroquine resistant strain of *Plasmodium falciparum* [Kumari *et al*. (2016)]. They also reported that the antiplasmodial activity may be due to the presence of phenols and alkaloids. The wealth of India (2003) reported that parthenin and some of its derivatives were evaluated for antimalarial activity against a multi-drug resistant strain of *Plasmodium falciparum*. Parthenin and related compounds have significant antimalarial action.

3.9 Antimicrobial activity

Researches have been conducted on plant based antimicrobials which are cost effective, eco-friendly and have enormous therapeutic potentials. Many investigations on the plant using the extracts from roots, stems, leaves, flowers, seeds and the whole plant by different solvents reported on the antimicrobial potentials of parthenium. It has also been reported that most plant based antimicrobials are free from side effects associated with synthetic antimicrobials. *Parthenium hysterophorus* have been reported as one of the plants potent antimicrobial properties because of the phytochemicals found in the plant [Malarkodi and Manoharan (2013), Kaur *et al*. (2016), Bagchi *et al*. (2016)].

3.10 Antifungal activity

Parthenium has the potentials of inhibiting the growth and development both plant and human pathogenic fungi. Antifungal activity against human pathogenic fungi was investigated by Rai and Upadhyay (1990) and Rao *et al.* (1985). They reported that the extract inhibited the growth of the fungi due to the presence of a compound known as sesquiterpine lactones. The following fungi were also effectively controlled by extracts of *P. hysterophorus*: *Fusarium solani* [Shazia and Sobiya (2012), Zunera *et al*. (2012)], *Alternaria alternata* Keissl [Rukhsana *et al*. (2004),Singh and Srivastava (2013), Gaurav *et al*. (2013)], *Candida albicans* [Malarkodi and Manoharan (2013)], *Fusarium oxysporum* [Harsha *et al*. (2011)], *Aspergillus niger* [Harsha *et al*. (2011), Rukhsana *et al*. (2003)], *Candida kefyr* [Malarkodi and Manohavan (2013)], *Aspergillus flavus* [Ajay *et al*. (2013)], *Drechslera tetramera* [Rahmat *et al*. (2011)], *Fusarium moniformes* [Rukhsana *et al*. (2004)], *Alternaria brassicae*, *A. brassicola* [Naina and Archana (2012)], *Sachromyces cerevisiae* [Rukhsana *et al.* (2004)], *Bipolaris oryzae* [Manimegalai and Ambikapathy (2012)]. *Fusarium solani*, which is the causative agent of an economically important potato disease called fusarium wilt was inhibited by extracts of of parthenium using solvents with varying polarity (aqueous, methanol and n-hexane) [Zaheer *et al*. (2012), Raghu *et al*. (2014), Bagchi *et al*. (2016)].

3.11 Antibactarial activity

A lot of studies have reported on the antibacterial potentials of parthenium extracts. The antibacterial is due to the presence of volatile oil in the plant which contains sesquiterpene and flavonoids and was found to be highly effective against gram positive and gram

negative bacteria [Chopra (1960)] and various species of dermatophytes [Dikshit and Dixit (1982)]. Many scientists have also reported on the antibacterial efficacy of parthenium extracts on the following species of bacteria; *Escherichia coli* [Harsha *et al*. (2011)], *Bacillus subtilis*, *Enterococcus* spp [Hina *et al*. (2011)], *Staphylococcus aureus* [Barsagade and Wagh (2010)], *Salmonella typhimurium*, *S. epidermidis*, *Vibrio cholera*, *Shigella flexneri* [Siddhardha *et al*. (2012)], *Pseudomonas aeroginesa* [Harsha *et al*. (2011)], *Mirococcus luteus* [Malarkodi and Manoharan (2013)], *Bacillus cercus* [Ajay *et al.* (2013)], *Klebsiella pneumonia*, *Enterobacter aerogenes* [Rahmat *et al*. (2011)], *Xanthomonas vesicatoria* and *Raltonia solanacearum* [Sukanya *et al*. (2009)].

3.12 Antiviral activity

Studies on the extracts of parthenium showed antiviral activity against the potato virus Y, which is a serious virus of chilli crops as it damage the crop extensively. As such it can be further developed and utilized as an antiviral agent against potato virus Y [The Wealth of India (2003), Raghu *et al*. (2014), Bagchi *et al*. (2016)].

3.13 Anti-Amoebic

Parthenium hysterophorus has been reported as a promising remedy against hepatic amoebiasis [Temesgen *et al*. (2017)]. *In vitro* evaluation of parthenium extracts against axenic and polyxenic cultures of *Enamoeba histolytica* were conducted. The extracts showed acute toxicity to the cultured organisms. The activity was due to the parthenin in the plant, which has comparable activity to that of metronidazole [Sharma and Bhutani (1988), Raghu *et al*. (2014), Bagchi *et al*. (2016), Meena *et al*. (2017)].

3.14 Lavicidal activity

Larvicidal activities of the extracts of *P. hysterophorus* have been reported by many authors. The methanolic extract of leaves showed 83-90% larvicidal activity against *Anopheles stephensi* larvae [Ahmad *et al*. (2011)]. Roots and stems extract demonstrated high larvicidal activity against the larvae of *Aedes aegypti* and could be used as a new mosquito larvicide. Khan *et al*. (2014) also reported that parthenium water extract proved highly toxic to the 3rd and 4th instar larvae of *Aedes albopictus* vector of Dengue fever. Fresh leaves water extracts of the plant gave 100% mortality against the larvae of *Aedes aegypti* within 30 minutes in 100ml solution [Amir *et al*. (2017)].

3.15 Trypanocidal

Crude 50% ethanolic extract of *P. hysterophorus* flowers showed activities against *Trypanosom aevansi*. The extract exerts antitrypanosomal effect at intraperitoneal doses of 100 and 300 mg/kg body weight when used for treatment of infected rats [Talakal *et al*. (1995)].

4. Agricultural uses of *Parthenium hysterophorus*

4.1 Biopesticidal activity

Continuous use of synthetic pesticides with similar mode of action had caused development of resistance by many organisms and also poses threats to human health and the environment. Recently, scientists have resorted into researching for pesticides from natural sources which will not constitute health problems to humans and be environmentally friendly. One of such natural source is plant allelochemicals. The allochemicals in *P. hysterophorus* have been reported by many researchers as having the potentials, which can be exploited as bioherbicides, bioinsecticides, nematicides, larvaecide and growth regulator [Getachew (2017)].

4.2 Bioherbicidal Activity

Extract of different parts of *P. hysterophorus* has shown phytotoxic effects on many aquatic [Pandey (1996)] and terrestrial weeds [Khosla *et al.* (980), Khosla and Sobti (1981), Kumari *et al.* (2016), Singh *et al*. (1992), Batish *et al*. (1997), Acharya and Rahman (1997)]. *Parthenium hysterophorus* extracts showed significant reduction in the weed density and has also shown allelopathic effects towards *Eragrostis tef*, *Cyperus rotundus*, *Digitaria sanguinalis*, *Portulaca oleracea*, *Echinochloa crus-galli*, *Euphorbia prostrate* and *Xanthium strumariam* [Maharajan *et al.* (2007), Nigatu *et al.* (2010)]. The sesquiterpene lactone parthenin is thought to be responsible for its allelopathic interference with surrounding plants by inhibiting cell division mediated through gibberellin and indole acetic acid [Kishor *et al*. (2010)]. The ability of the plant extract to show phytotoxic effect on both terrestrial and aquatic weeds is a strong indication that the weed can be a potential bioherbicide. However, there is need for further studies to address other issues like the mode of action specific doses for particular

weed species, etc.

4.3 Insecticidal

Parthenin is the active compound present in the extract of *P. hysterophorus*. Parthenin was reported to have antifeedant and insecticidal activity on *Calobrochus maculatus* (pest of stored grains) and *Spodoptera litura* (cotton pest) [Gajendran and Gopalan (1982), Bhaduri *et al*. (1985), Dhandapani *et al*. (1985), Datta and Saxena (2001)]. The compound present in *P. hysterophorus* is also known to show activity against termites, cockroaches [Tilak (1977)] as well as migratory grasshoppers, *Melanoplus sanguinipes* [Picman *et al*. (1981), Fagoonee (1983)].

The plant extract also inhibited cholinesterase of cockroach brain as done by organophosphorus pesticides [Gajendran and Gopalan (1982)]. Petroleum ether extracts of leaves, stem and inflorescence of the weed at different concentrations *viz.*, 500, 1000, 2000 and 5000 ppm significantly decreased the life span and progeny production of mustard aphid, *Lipaphis erysimi* [Sohal *et al.* (2002)]. Decoction of the plant can be used as a flea-repellent for dogs and other animals [Maishi *et al*. (1998)].

4.4 Nematicidal

Extracts of leaves or the whole plant (leaves, stems, inflorescence and roots) have also been found to be juvinomimetic [Rajendran and Gopalan (1980) and nematicidal [Gommers (1973)] on *Meloidogyne incognita* and *Helicotylenchus dihystera* [Hassan and Jain (1984)] with beneficial effects on crop plants [Bala *et al*. (1986)]. In a related development crushed leaves admixed into the soil are used to reduced root galling in papaya caused by *M. incognita* [De la Fuente *et al*. (2000)].

4.5 Compost as green manure

Studies revealed that *P. hysterophorus* contains both micro and macro elements such as N, P, K, Ca, Mg and chlorophyll, which can be utilized in making compost [Kishor *et al*. (2010), Khan *et al*. (2011)]. The compost contains two times or more N, P, and K than Farm Yard Manure (FYM) are necessary for proper growth and development of agricultural crops resulting in higher yields [Channappagoudar *et al*. (2007), Kishor *et al*. (2010)]. More so many studies revealed that the integrated use of parthenium in soil modifies the physico-chemical, biological and nutritional quality of the soil. Incorporation of organic waste of parthenium enhanced the moisture content of the soil to the tune of 45.5 to 77.4% as compared to application of nitrogen alone in maize crop [Getachew (2017)].

4.6 Formulation of animal feed

Parthenium hysterophorus leaves and stems dried fibres free of parthenin contain 1.6-2.4% of N and can be used as cattle feed [Narasimhan *et al*. (1993)]. It has also been reported to be a valuable source of potash, oxalic acids and high-quality protein (HQP), which can be used in animal feed [Mane *et al*. (1986)].

4.7 Biochar Preparation

Inclusion of biochar produced from parthenium to the soil boost the nutrient status as well as its quality as demonstrated by the growth maize, with improvement in physiological activities such as respiration, enzyme activities (catalase and dehydrogenase), reduction in soil stress etc. *Parthenium hysterophorus* biochar has been successfully prepared via its transformation to change carbon for adverse carbon dioxide discharge [Kumar *et al*. (2013), Saini *et al*. (2014)]. In the process of charring, a chemical ambrosin present in parthenium, having phototoxic aftermath was vanished through deterioration at elevated temperature. Furthermore, incorporation of high quantity of biochar to the soil did not show any adverse impact [Patel (2011), Saini *et al*. (2014)].

5. Industrial Uses

5.1 As additive in cattle manure for biogas production

In the wake of the global energy crisis, energy generation through other means is been research into and one of such approaches is from bio wastesby anaerobic digestion which has attracted immense attention. Energy crops are likely to be future sources of digesterfeed stocks for methane generation. *Parthenium hysterophorus* was mixed with cattle manure at a 10% level and allowed to digest anaerobically at room temperature in 3-l batch digesters. The chemical changes during the course of digestion and the effect of digested slurry (inoculum) on biogas production were investigated and significant increase in methane content was achieved. The methane content of the gas varied between 60 and 70% [Gunaseelan (1998)]. The *P. hysterophorus* should be seriously considered as a substrate for the production of biogas

in India via anaerobic digestion, considering the abundance of this weed and large quantity of livestock [Patel (2011)]. The utilization of this weed as an additive in the biogas production therefore serves as a control measure against the invasive weed *i.e* control by utilization.

5.2 Use as substrate for commercial enzyme production

Parthenium hysterophorus as substrate for enzyme production xylanases are hydrolytic enzymes that cleave xylans. The end products of xylan degradation have industrial applications for biofuel, artificial sweetener, animal feed production, baking and textile industry, clarification of fruit juices and coffee extraction. Besides, there has been an increasing interest in using xylanase for ecofriendly bleaching of pulp in paper industries. The potential of *P. hysterophorus* as low-cost raw material forxylanase production was studied by Dwivedi *et al*. (2009)**.** They investigated xylanase production from a mutant of *Penicillium oxalicum* in submerged fermentation. Considerably higher level of the enzyme production in medium containing *P. hysterophorus* confirms the feasibility of using this cheap resource as an alternative carbon source to save costs of the enzyme production process [Sahrawat *et al*. (2018)].

5.3 Removal of heavy metals and dyes

Sulphuric acid-treated parthenium showed nickel removal and methylene blue dye absorbing efficiency from wastewater or industrial wastes. Ni removal was maximum at pH 5.0 and achieved within 4 hours after the start of every experiment. Dye adsorbing ability was also found to be comparable to commercial adsorbents. The cadmium adsorbing ability of parthenium was also explored and the result showed maximum absorbing ability at pH 3-4 with recovery of 82% with 0.1 M HCl as effluent [Ajmal *et al*. (2006), Patel (2011)]. Activated carbon prepared from parthenium showed cresol (a phenol derivative) adsorbing ability comparable to commercial grade activated carbon [Singh *et al*. (2008), Patel (2011)]. As, heavy metals (Ni and Cd), cresols and dyes caused cancer and other diseases in humans so, their treatments or removal from industrial wastes becomes necessary, which make parthenium a better, cheaper and eco-friendly source as an adsorbent [Khaket *et al*. (2015)].

5.4 Pulp and Paper making

Parthenium have been reported to be a potential source of affordable raw material for pulp and paper production, having enough strength as well the requisite quality for many commercial productions. Chemical analysis of *P. hysterophorus* shows that the weed is loaded with large quantity of lignocellulose biomass, which is made up of lignin (13-17%), hemicellulose (21%) and cellulose (28%) [Shubhaneel *et al*. (2013), Saini *et al*. (2014)]**.**

6. Conclusion

Parthenium hysterophorus is an invasive weed with high invasion potential of taking over an area within a short time through the release of allelopathic chemicals via its roots into the soil. These chemicals include terpenoids, volatile oils and flavonoids as well as amino acid, sugars and phenolic derivatives; caffeic acid, vanillic acid, anisic acid, panisic acid, chlorogenic acid and parahydroxy benzoic acid are parthenolide (the major sesquiterpene lactone). These compounds are harmful as well as beneficial to humans, animals, plants, microorganisms and the physical environment. These allelopathic chemicals are reported to cause diseases in humans and animals, yield reduction in crops, damage to the ecosystem, tainting of meat and milk in animals, inhibition of the growth of N fixing bacteria and the reduction in pasture quality. The chemical compounds present in the weed are also reported to show beneficial effects in biological activities in animal and human models indicating that the weed can be used as traditional medicine (for the treatment of illnesses such as headache, stomach ache, diarrhoea etc.), as anti-diabetic, thrombolytic, antioxidant, anti-tumor(anti-cancer), anti-inflammation, wound healing, antimalarial insecticidal, antifeedant, larvicidal, herbicidal, antifungal, antiamoebic, trypanocidal, antibacterial, antiviral, antioxidant, compost making, biogas production, animal feed formulation, enzyme production and removal of heavy metal and dyes, biochar production and paper and pulp making. However, as *P. hysterophorus* is a toxic plant, further scientific researches and investigations are essential to establish it role as a plant with medicinal, agricultural and industrial potentials.

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