

Phytochemistry and Antimicrobial Activity of *Parthenium hysterophorus* L.: A Review

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Abstract: *Parthenium hysterophorus* is the seventh noxious alien species distributed in different part of the world. This dangerous plant is known for its negative impact on biodiversity, agriculture and human being. *Parthenium* plant is capable of causing allergic respiratory problems, contact dermatitis, diarrhea, skin allergy, skin rashes excessive water loss, mutagenicity, both in human and livestock. There are different attempts to control parthenium weed in which most of the methods are not successful due to rapid re-infestation of the plant. Even though parthenium plant is known for its toxicity, it is traditionally used for the treatment of fevers, headaches, wounds, diabetes, diarrhea, anemia, heart troubles and malaria to list some in different part of the world. The aim of this review article is mainly to explore the chemical components and antimicrobial property of *parthenium hysterophorus*. In this review the effect of parthenium on environment, human being and agriculture and major controlling practices have also been summarized.

Keywords: *Parthenium hysterophorus*, Phytochemistry, Antimicrobial Activity

1. Introduction

Parthenium hysterophorus L. is an alien invasive weed which is cited as the seventh most devastating and hazardous weed. It is a fast maturing annual herb with a deep tap root and may eventually reach a height of 2m. The seed of parthenium mainly disperses through flooding, water currents, movement of vehicles, machinery, livestock, grain, fodder, and to a lesser extent by wind [1, 2].



Figure 1. Matured *parthenium hysterophorus* plant.

Parthenium hysterophorus L. is originated as a result of natural hybridization between *Parthenium confertum* and *Parthenium bipinnatifidum* [3]. It adapts various agro-climatic conditions and almost distributed itself to variety of growing environmental conditions [4]. Some of the countries where this plant is distributed includes: India, China, Taiwan, Pakistan, Nepal, Sri Lanka, Bangladesh, Vietnam, Pacific Islands, Ethiopia, Kenya, Madagascar, South Africa, Somalia, Mozambique, Zimbabwe and several countries of South and Central America [5, 6].

This noxious weed is known for its adverse effect on environment, biodiversity, agriculture, and health of animals and human beings. This is because of the toxic chemicals produced by parthenium plant [7, 12].

1.1. Impact on Biodiversity

Different investigations have shown the treats of *Parthenium* on the structure and diversity of plant communities. Allelochemicals released from parthenium is capable of changing the physicochemical characteristics of the soil. It affects the moisture content, temperature, pH, organic matter, carbon, nitrogen and phosphorus content and soil microbial activity [8-10]. The change in property of the soil due to introduction of allelochemicals affects the reproduction,

growth and survival of other nearby plant [11-14]. Generally parthenium is intended to pose a serious threat to the biodiversity by invading new surroundings and by reducing or totally replacing the indigenous species where it causes total habitat change [15].

1.2. Impact on Agriculture

Parthenium is among well-known weed causing serious problem to agriculture. It reduces agricultural production by suppressing agricultural yield from crops and animals [16]. The adverse impacts of *parthenium hysterophorus* on agriculture have been reported by several authors. It reduces production from livestock by causing various health problems and also by causing scarcity of animal fodder by invading pasture lands. Parthenium is poisonous to livestock when it is consumed or repeatedly in contact with the weed. Those animals can encounter death, rashes on their body and udders, alopecia, loss of skin pigmentation, allergic skin reactions, dermatitis, diarrhea, anorexia, pruritus. Parthenium can also affect the psychological behavior of animals [18]. During scarcity of fodder cattles, sheeps and goats are forced to eat parthenium which can taint their meat and make diary milk unpalatable due to its irritating odor [12, 17].

metabolites which may be introduced to the soil through leaching, root exudations and decay of allelopathic plants as parthenium [11]. This toxic chemical inhibits seed germination, radical growth and seedling growth which are responsible for the reduction in the distribution of other plants [20].

The major allelochemicals present in parthenium includes sesquiterpene lactones mainly parthenin and phenolic acid as: gallic acid, chlorogenic acid, ferulic acid, caffeic acid, anisic acid, vanillic acid, fumaric acid, hysterin, p-caumaric acids, hymenin, and ambrosin Figure 2 [19, 20].

Different investigations have been performed to show the impact of parthenium weed on the production of different agricultural crops. Parthenium is known by reducing the yield from agricultural crops as: wheat (*triticum aestivum* L.) [21], maize (*Zea mays* L.) [22-24], teff (*erragrostic teff*) [16], sorghum (*Sorghum bicolor*) [25], soybean (*Glycine max* L.) [26], cotton (*Gossypium hirsutum* L.) [11], haricot bean (*Phaseolus vulgaris* L.) [20], chickpea (*Cicer arietinum*) [9], tomato (*Solanum lycopersicum* L.) [27], radish (*Raphanus sativus*) [9], brassica species (*Brassica campestris*, *Brassica oleracea* and *Brassica rapa*) [28, 23] to list some of them.

1.3. Impact on Human

There are different investigations reporting the impact of *Parthenium hysterophorus* on human health. Parthenium causes different health problems viz., asthma, bronchitis, contact dermatitis, eye irritation, rhinitis, hay fever, allergy, photo-dermatitis, skin rashes, peeling skin, puffy eyes, excessive water loss, swelling and itching of mouth and nose and eczema [6, 29, 30, 31].

2. Phytochemistry of *P. hysterophorus*

The phytochemical investigation of *P. hysterophorus* revealed the presence of various chemical constituents viz., alkaloids, proteins, saponins, tannins, carbohydrate, glycosides, terpenoids, steroids, volatile oils, amino acids, amino sugars, lignans, phenolic compounds, flavonoids, metallic elements, organic acids, terpenoids and others [32-36].

The mineral composition of *P. hysterophorus* has been analyzed by Rahmat *et al.* In their investigation they has showed the presence of significant amount of potassium, calcium, magnesium, sodium, iron, zinc, copper, molybdenum, lead, lithium, nickel, cadmium, chromium and manganese in parthenium plant [37,38].

The phenolic acids isolated from *parthenium hysterophorus* plant parts extracted in different organic solvents includes: caffeic acid ($C_9H_8O_4$), p-coumaric acid ($C_9H_8O_3$), p-anisic acid ($C_8H_8O_3$), ferulic acid ($C_4H_4O_4$), fumaric acid ($C_4H_4O_4$), p-hydroxy benzoic acid ($C_7H_6O_3$), chlorogenic acid ($C_{16}H_{18}O_9$), neochlorogenic acid ($c_{16}H_{18}O_9$), protocatechuic acid ($C_7H_6O_4$), aerulic acid, and vanillic acid ($C_4H_4O_4$) [35].

Among flavovoids: quercetageitin-3,7-dimethyl ether, apigenin, kaempferol-3-o-glucoside, quercetin-3-o-glucoside, kaempferol-3-o-glucoside, luteolin, lignin, jaceidin,

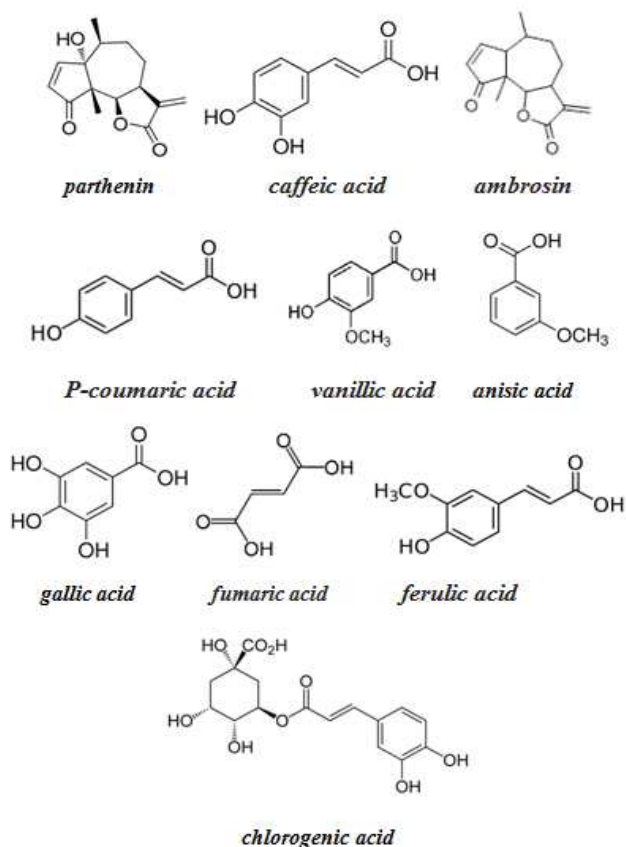


Figure 2. Chemical structure of major allelochemicals found in parthenium plant.

The introduction of allelochemicals to the soil by any means affects the growth, reproduction and development of many plants. Allelochemicals are mostly secondary plant

syringaresinol, santin, chrysoeriol, kaempferolglucoside, centaureidin, 6-hydroxykaempferol-3,6-dimethylether, tanetin (6-hydroxykaempferol-3,6,4-trimethylether), quercetinglucoside, 6-hydroxykaempferol-3,7-dimethylether and kaempferolglucoarabinoside can be listed [6, 39, 40].

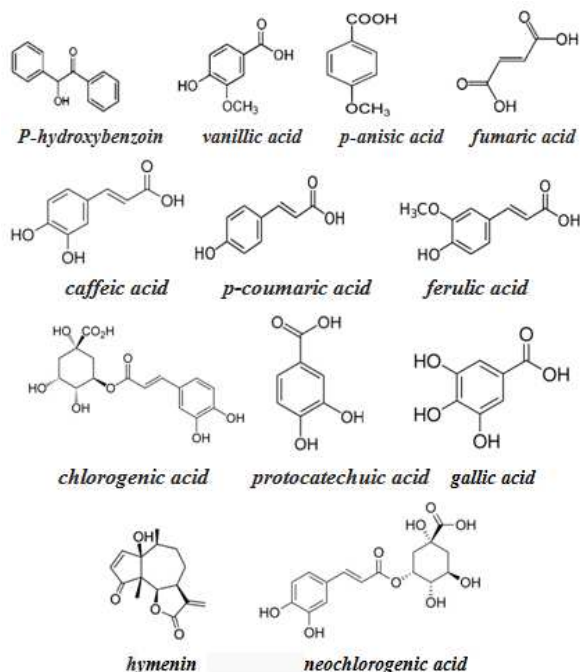


Figure 3. The molecular structure of major phenolic acids in *parthenium hysterophorus L.*

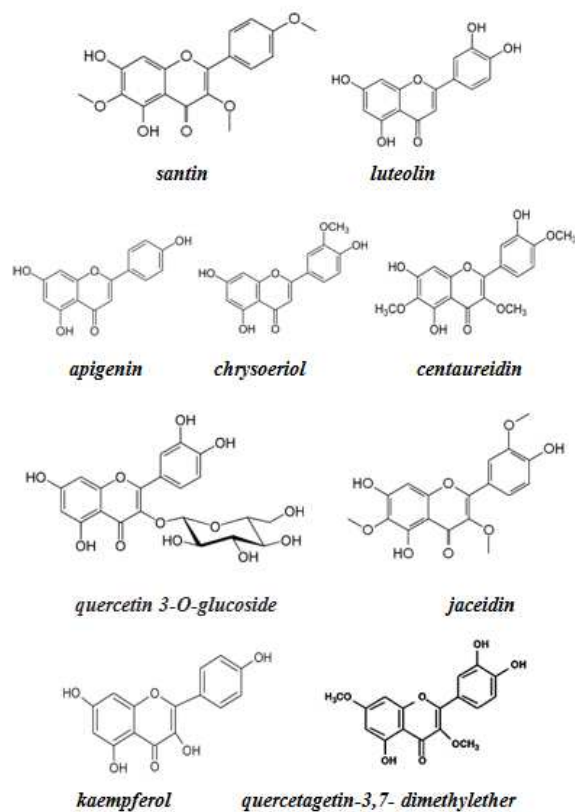


Figure 4. The molecular structure of major flavonoids in *parthenium hysterophorus L.*

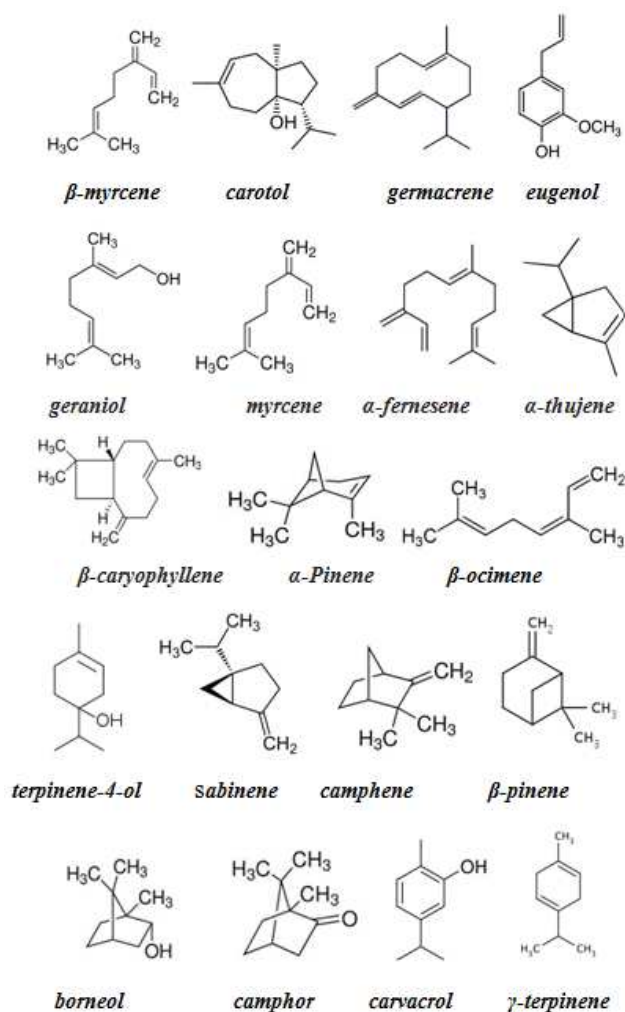


Figure 5. The chemical structure of some of the trace, minor and major oils in *parthenium hysterophorus L.*

A report from different investigations revealed the presence of trace, minor and major essential oils extracted from different plant parts of *parthenium*. The yield of extraction varied from 0.04-0.05 % (w/w). Trace oils extracted includes: α -thujene, p-cymene, cis- β -ocimene, δ -elemene, trans- α -bergamotene, α -terpinene, dodecane, benzothiazole, nerol, α -cubebene, tetradecane, oxo- α -ylangene. The principal oils extracted from *parthenium* can be listed as: geraniol, germacrene-D, myrcene, α -farnesene, β -caryophyllene, trans- β -ocimene, (trans, trans)- α -farnesene, carotol, caryophyllene oxide, and 1-octen-3-ol, are the major constituents [41,42].

There are also diverse essential oils extracted from *parthenium* plant with lower concentrations vis., α -pinene, camphene, β -pinene, sabinene, limonene, linalool, bicyclogermacrene, α -humulene, trans- β -farnesene, β -cubebene, β -elemene, β -phellandrene, δ -cadinene, β -sesquiphellandrene, carota-5,8-diene, α -cadinol, 3-octanol, p-cymene, phytol (1.0%), pentadecan-2-one, citronellol, neral, bornyl acetate, tridecane, β -bourbonene α -terpineol γ -terpinene to list some them. Among essential oils isolated from *parthenium* sesquiterpenes are the principal component

which is about 50% percent of the oil extracted. Monoterpene which is about 20% and oxygen-bearing sesquiterpenes (6%) ranks second and third respectively [41,42].

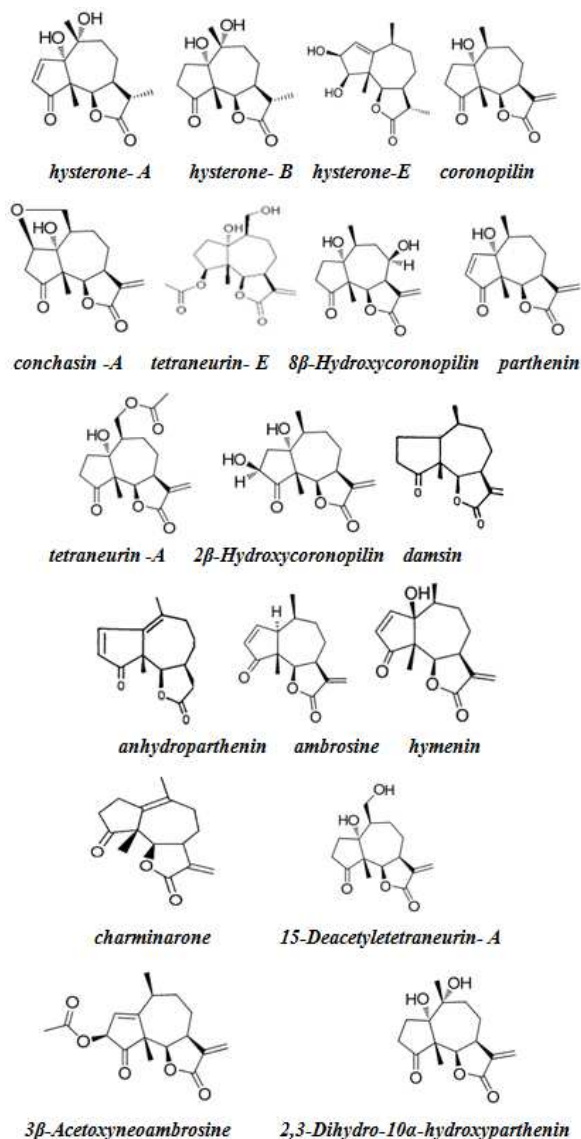


Figure 6. Chemical structures of major pseudoguaianolides of *parthenium hysterophorus* L.

The extract of different parts of parthenium plant contains various pseudoguaianolide as: parthenin, anhydroparthenin, 2,3-dihydro-10 α -hydroxyparthenin, 8 β -hydroxyparthenin, ambrosin, 10 α -hydroxyparthenin, tetraeurin-A, tetraeurin-E, hymenin, 15-deacetyltetraeurin-A, damsine, 2 β -hydroxycoronopilin, 8 β -hydroxycoronopilin, hysteron, scopoletin, conchasin-A, 3 β -acetoxyneoambrosine, ambrosanolides, 8 β -acetoxyhysteron-C, deacetyltetraeurin-A, hysteron A-E, 8 β -acetoxyhysteron-C, dihydroxyparthenin, acetylated pseudoguaianolide, coronopilin, 13-hydroxyparthenin, charmarone, dihydroisoparthenin,

13-methoxydihydroparthenin, balchanin, costunolide, 2 β ,13 α -methoxydihydroparthenin, epoxyartemisin, 8 α -hydroxyestaatin, 11,13-dihydroparthenin, 13-

methoxy-11,13-dihydroambrosin, 3- β -hydroxycostunolide, 5- β -hydroxyreynosin 13-methoxydihydroambrosin, 1- β -hydroxyarbusculin, and 13-methoxy-11,13-dihydro parthenin [43-46].

3. Antimicrobial Activity

Even though *Parthenium hysterophorus* is known for its toxicity, in different parts of the world as Jamaica, Trinidad, Mexico, US Virgin Islands, Alaska and India it is used to prepare traditional medicine. Parthenium is used to treat wounds, diabetes, ulcerated sores, fever, diarrhea, anemia, heart troubles, malaria, headache, inflammatory, urinary infections, skin rashes, neurological disorder, and female reproductive problems. This can be related to the fact that parthenium produces secondary plant metabolite chemicals with potent antimicrobial activity [49, 50].

Plant based antimicrobials have enormous therapeutical potential and they are also cost effective as well as ecofriendly. Mostly plant based antimicrobials are free of side effects associated with synthetic antimicrobial. *P. hysterophorus* can be listed among various medicinal plants with potent antimicrobial property. There are so many investigations reporting the antiviral, antifungal, antibacterial, antihelminthic, antimolluscal, and antiinflammatory properties of parthenium [47,48].

Antifungal property of *p. hysterophorus* has been reported by different investigators. Both plant and human pathogenic fungi viz., *Fusarium Solani* [51,52], *Alternaria Alternata* [53,54], *Candida albicans* [56], *Fusarium oxysporium* [57], *Aspergillus niger* [57-59], *Candida kefyr* [56], *Aspergillus flavus* [60], *Drechslera tetramera* [59], *Phoma glomerata* [59], *Aspergillus fumigates* [37], *Drechslera hawaiiensis*, *Alternaria alternata keissl* [61], *Fusarium moniliforme* [61], *Alternaria brassicae*, *Alternaria brassicicola* [62], *Saccharomyces cerevisiae* [60], *Bipolaris oryzae* [63] were reported.

Antibacterial efficacy of *Parthenium hysterophorus* has also been reported by various scientists as: *Escherichia coli* [57], *Bacillus subtilis*, *Enterococcus spp.* [64], *Staphylococcus aureus* [58], *Salmonella typhimurium*, *S. epidermidis*, *V. cholerae*, *Shigella flexneri* [65], *Pseudomonas aeruginosa* [57], *Micrococcus luteus* [55], *Bacillus cereus* [60], *Klebsiella pneumoniae*, *Enterobacter aerogenes* [37], *Xanthomonas vesicatoria*, *Ralstonia solanacearum* [48].

4. Controlling Mechanism

There are several methods available for controlling parthenium weed. Some of the methods are: manual, chemical, bioherbicidal, biological control, competitive replacement by other plants, and managing the weed through proper utilization.

4.1. Manual Control

Hand weeding, plowing, firing and mowing are some of the physical or manual method of controlling the weed. Hand

weeding is not an effective method due to several reasons. The first reason can be that, during hand pooling a matured seed will drop off and increase the area of infestation. The second reason can be related to its effect on health. Thirdly it is labor intensive and not economical and beside it needs repeated control because of the rapid re-growth of the weed. Ploughing can be considered as the best method compared to that of hand weed because of the absence of contact with weed but it has to be done before the plants reach the flowering stage. Burning and mowing or cutting the plant off at the ground level can also be used as a control strategy for parthenium weed [66].

4.2. Chemical Control

Chemical control is an effective and quick way of controlling parthenium weeds. Among various synthetic herbicides buctril super, chlastox, chlorimuron ethyl, metasulphuron atrazine, dicamba, picloram, glyphosate, metribuzin are to list some of them [67]. Even though, chemical control is an efficient and prompt solution of controlling parthenium weed it is not without a defect. Synthetic herbicide poses serious ecological and health problems. During application of synthetic herbicide, may be herbicide resistance weed biotype emerges and also some of the herbicides may not be selective in which it may kill untargeted plants (crops). Therefore a great care must be taken during handling and application of these chemicals [66].

4.3. Bioherbicidal Control

The most challenging problem with synthetic herbicides is its toxicity or the problem it cause to the environment. This fact attracts the attention to replace synthetic herbicides with naturally existing plant based herbicides. Certain plants are known for their allelopathic nature and can be used as a potent herbicide against parthenium weed. There have been different reports on the herbicidal property of different plant extracts. Some of the plants reported so far includes: *Tagetes erectus* [68], *Dicanthium annulatum*, *Cenchrus pennisetiformis*, *Sorghum halepense* [69], *Azadirachta indica*, *Aegle marmelos*, *Eucalyptus tereticornis* [70], *Sorghum bicolor*, *Imperata cylindrical*, *Mangifera indica* L. [71], *Zingiber officinale*, *Allium cepa* L., *Allium sativum* L. [72], *Andrographis paniculata* [73], *Cymbopogon citratus*, *Eucalyptus citrodora*, *Cinnamomum camphora* [74, 75], *Cassia occidentalis* [76], *Sclerotium rolfsii* [77], *Cophoma herbarum* [78], *Helianthus annuus*, *Oryza sativa* [79], *Datura metal*, *Nerium oleander* [80] and *Alstonia Scholaris* [71].

4.4. Control by Competitive Replacement

Parthenium can also be controlled by planting competitive plants which can dominate the weed and reduce its population. This can be done by planting species like *Cassia sericea*, *Croton bonplandianus*, *C. sparsiflorus*, *Amaranthus spinosus*, *Sida acuta*, *Tephrosia purpurea*, *Stylosanthes scabra*, *Cassia tora*, *Tagetes spp.*, *Croton bonplandianum*, *Hyptis suaveolens*, *Sida spinosa*, *Mirabilis jalapa* [81-83].

4.5. Biological Control

Biological control of parthenium is the most economical, environmentally safe as well as ecologically viable method. Several insects and pathogens have been tried in different parts of the world in different time. Some of the biocontrol agents utilized so far includes; *Epiblema strenuana* (stem-galling moth) [84], *Bucculatrix parthenica* (leaf-mining moth), *Platphalonidia mystica* (stem-boring moth), *Zygogramma bicolorata* (leaf feeding beetles) [85-87], *Listronotus setosipennis* (stem-boring weevil), *Conotrachelus albocinereus* (stem-galling weevil), *Semicronyx lutulentus* (seed-feeding weevil), *Carmenta ithacae* (root-boring moth), *Puccinia abrupt* (winter rust fungus) [88], and *Puccinia melampodii* (summer rust fungus) [87].



Zygogramma bicolorata



Epiblema strenuana larva



Leaf infection caused by *Puccinia*



Carmenta sp.

Figure 7. Damage caused by *Z. bicolorata*, *Epiblema strenuana* larva, *Puccinia abrupt*, *Carmenta* sp. on parthenium [70, 89].

4.6. Controlling by Utilization

Management by utilization is the most promising way of controlling this obnoxious weed. There are so many beneficial aspects of parthenium in which it can be used as a raw material or as additives to prepare: feed stock [90], forage [91], herbicide [92-94], pesticide [95], insecticide [96,97], ethanol [98,99], compost [100-103], green manure [104], synthesis of nanoparticles [105,106], feed additive for silkworm [107], decolorizing agent [108] can be listed among various uses of this plant.

5. Conclusion

Parthenium plant is mostly known for its traits on natural ecology and its adverse effect on human and animal health. There are different techniques utilized so far to control this toxic weed. The most promising way is to manage the weed by proper utilization. Parthenium plant can be used as herbicide, pesticide, insecticide and also as a raw material or as additives in different industry as paper, pulp and dye industries to list some of them. Different investigation has also shown the presence of essential compounds extracted from parthenium plant with potent antioxidant, antimicrobial, anticancer properties. Therefore parthenium plant can be considered as an alternative medicinal plant if further investigation is performed.

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