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RESEARCH ARTICLE

PARTHENIUM: CHARACTERISTICS, ALLELOPATHIC EFFECTS AND ALTERNATIVE USES

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ABSTRACT

In this review article we have described the systematic position, common names, characteristics, chemicals isolated, harmful effects on ecosystem, allelopathic effects of leaf and stem extract of *Parthenium hysterophorus* on some selected seeds of crop plants such as *Phaseolus mungo*, *Cicer aeritinum*, *Pisum sativum*, *Cajanus cajan* and *Zea mays* in brief. Effects on animals and human beings have also been discussed. For the control of *Parthenium* management practices such as manual, chemical, bioherbicidal, biological and by useful utilization have been discussed. There is a need to develop integrated management programme for eradication and to check the further spread of *Parthenium*.

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INTRODUCTION

Characteristics of *Parthenium*

Domain: Eukaryota
Kingdom: Plantae
Phylum: Spermatophyta
Sub-Phylum: Angiospermae
Class: Dicotyledonae
Order: Asterales
Family: Asteraceae
Genus: *Parthenium*
Species: *hysterophorus*

Parthenium is commonly called as congress grass, carrot grass, feverfew, ragweed Parthenium (USA), white head (English), in India it is locally called as chatak chandani, gazar ghas and thandi booti. *Parthenium* is an annual plant with a deep tap-root and an erect much-branched stem. Mature stems are greenish and longitudinally grooved, covered in small stiff hairs (trichomes). It usually grows 1-2m. tall. Leaves are simple, pale green, lobed, sessile, irregularly dissected, hairy and alternately arranged with stalk (petioles) up to 2cm long and form a basal rosette during the early stages of growth.

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The number of leaves per plant is 6 to 55. The flowers are arranged in capitulam, creamy white in colour, borne in profusion at the tips of the stems. Small flower heads are arranged in clusters and its colour changes to light brown, when seeds are mature. Flowering can occur at any time of the year, but is most common during the rainy season. Each flower contains five seeds, which are wedge-shaped, black, 2mm long with thin white scales. The seeds are dispersed by wind, water, animals, vehicles and farm machinery (Shikha and Jha 2016 a). It contains special characters such as: high germination ability, large seed production capacities, high survival rate, extreme adaptability in different habitats, easy dispersal of seeds, high allelopathic impact and completes life-cycles within four weeks (Shikha and Jha 2016 a).

Distribution in India

In India *Parthenium* is considered as worst weed due to its allelopathic effects on crop production and harmful effects on human beings and animals. It is spread in all states of India. The highly infested states are A.P., Bihar, Chhattisgarh, Delhi, Haryana, Karnataka, Maharashtra, M.P., Punjab, Tamil Nadu and U.P. in terms of density and infestation level. The infestation level is medium in Assam, Gujarat, H.P., Jharkhand, J.K., Uttarakhand, Orissa, W.B., and Rajasthan and low level of infestation are in Andman and Nikobar, Arunachal Pradesh, Daman and Diu, Goa, Kerala, Manipur, Mizoram, Meghalaya,

Nagaland, Pondicherry and Sikkim. *Parthenium* in India has spread in extreme high temperature state i.e. in Rajasthan to low temperature states J.K. and H.P.; and in high rainfall in north east states to high humidity state of Kerala (Kumar 2012). It was reported from Pune in 1955 and in 1975 five million hactares of land was covered by *Parthenium* and in 2012 it covered around 35 million ha of wasteland, cropland and forest lands. It has widely covered all states of India (Kumar 2012). *Parthenium* has spread in all types of cereals, pulses, cash crops, vegetable crops, pastures, forests, plantations etc. For the survival of elephants the high court of India has instructed the sate and central governments to constitute a task force to manage *Parthenium*, *Lantana, Chromolaena* and other exotic weeds which have threatened the avaibility of palatable vegetation (Kumar 2012).

Chemical Composition

Parthenium consists of about 16 species (Marwat *et al*.2015). Marwat *et al*. (2015) have collected data on chemicals isolated from *Parthenium* by various authors and about 123 compounds have been reported. All parts of *Parthenium* (stem, leaves, leafhair, flower, pollengrain etc) contain toxic and inhibitory constituents such as terpenoids, sesquiterpene lactones (Parsons and Cuthbertson. 2001; Boon and Smith 2004; Pareek *et al*. 2011; Barnes *et al*. 2007); volatile oils (Barnes *et al*. 2007; Pareek *et al*. 2011); amino sugars (Gupta *et al*. 1996); phenolic derivatives (Parsons and Cuthbertson 2001); flavonoids (Pareek *et al*. 2011) etc. *Parthenium* also produces several bioactive molecules which are rich source of various types of medicines such as apigenin (Kuhn and Winston 2007; Zhou *et al*. 2011a); borneol (Barnes *et al*. 2007; Zhou *et al*. 2011f); camphor (Barnes *et al*. 2007; Zhou *et al*. 2011b); canin (Zhou *et al*. 2011b); charminarone (Venkataiah *et al*. 2003); coronopilin (Zhou *et al*. 2011b); luteolin; Zhou *et al*. 2011c); parthenin (Zhou *et al*. 2011d); parthenolide (Khun and Winston 2007; Zhou *et al*. 2011d); α- pinene (Barnes *et al*. 2007; Zhou *et al*. 2011d); reynozin (Boon and Smith 2004; Zhou *et al*. 2011d); santamarin (Boon and Smith 2004; Zhou *et al*. 2011d); santin (Zhou *et al*. 2011d); trtraneurin E (De la Fuentc *et al*. 2000; Zhou *et al*. 2011e); caffic vanllic, forfulic, chlorogenic and anisic acids (Parsons and Cuthbertson 2001).

Parthenium secretes various types of chemicals such as: alkaloids, proteins, saponins, tannins, carbohydrates, glycosides, terpenoids, steroids, volatile oils, amino acids, amino sugars, lignins, phenolic compounds and others. Some mineral composition in significant amount like: potassium, calcium, magnesium, sodium, iron, zinc, copper, molybdenum, lead, lithium, nickel, cadmium, chromium and manganese are present in *Parthenium* plant. Phenolic acids isolated from *Parthenium* are mainly caffic acid, p- coumaric acid, p- anisic acid, ferulic acid, fumaric acid, p-hydroxy benzoic acid, chlorogenic acid, neochlorogenic acid, protocatechuic acid, aerulic acid and vanillic acid. Among flavovoids: quercetagetin-3, 7-dimethyl ether, apigenin, kaempferol-3-0-glucoside, quercetin-3-0-glucoside, kaempferol-3-0-glucoarabinoside, luteolin, lignin, jaceidin, syringaresinol, santin, chrysoeriol, kaempferolglucoside, centaureidin, 6-hydroxykaempferol-3, 6-dimethylether, tanetin (6-hydroxykaempferol-3, 6, 4- trimethylether), quercetinglucoside, 6- hydroxykemferol- 3, 7- dimethylether and kaempferol glucoarabinoside have been isolated. Oils extracted in trace ammount include: α-thujene, p-cymene, cis-β-ocimene, δ-elemene, trans α- bergamotene, α- terpinene, dodecane, benzothiazole, nerol, α- cubebene, tetradecane and oxo- α- y langene. The principal oils extracted from *Parthenium* are listed as: geraniol, germacrene- D, myrcene, α-fernesence, β- caryophyllene, trans- β-ocimene, (trans, trans)-α-farnesence, carotol, caryophyllene oxide and 1- octen-3-ol, are the major constituents. 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-phelandrene, δ-cadinene, β-sesquiphelandrene, carota-5, 8-diene, α-cadinol, 3-octanol, p-cymene, phytol (1.0%), pentadecan-2-one, citronellol,neral, borny acetate, tridecane, β-bourbonene α-terpineol, γ-terpinene to lists some them. The extract of different parts of *Parthenium* plant contains various pseudoguaianolide as: parthenin, anhydroparthenin, 2,3-dihydro-10α-hydroxyparthenin, 8β-hydroxyparthenin, ambrosin, 10α-hydroxyparthenin, tetraneurin-A, tetraneurin-E, hymenin, 15-deacetyltetraneurin-A, damsin, 2β-hydroxycoronopilin, 8β-hydroxycoronopilin, htsterin, scopoletin, conchasin-A, 3β-acetoxyneoambrosine, ambrosanolides, 8-β-acetoxyhysterone-C, daecetyltetraneurin-A, hysterone A-E, 8- β-acetoxyhysterone-C, dihydroxyparthenin, acetylated pseudoguaianolide, coronopilin, 13-hydroxyparthenin, charminarone, dihydroisoparthenin, 13-methoxydihydroparthenin,balchanin, costunolide, 2β, 13α-methoxydihydroparthenin, epoxyartemorin, 8-α-hydroxyestaiatin, 11,13-hydroparthenin, 13-methoxy-11,13-d ihyydroambrosin, 3-β-hydroxycostunolide, 5- β-hydroxyreynosin 13-methoxydihydroambrosin, 1- β-hydroxyarbusculin, and 13-methoxy-11,13-dihydroparthenin (Bezuneh 2015).

Harmful Effects

(A) Effects on Ecosystems

(i) Natural Vegetation: It effects are on total change in habitat in grassland, woodlands, riverbanks, floodplains etc. It is aggressive colonizer of wasteland, roadsides, railway sides, cultivated fields etc. It is a herbaceous menace. Species composition of abandoned cropland is affected by *Parthenium* (Shikha and Jha 2016 b).

Parthenium is among well-known weed causing serious problem on crop production due to presence of these allelochemicals like: parthenin, hysterin, hymenin and ambrosin. It inhibits the germination and growth of pasture grasses and other plants. This may reduce nitrogen fixing ability to pulse crops. It induces changes in the physical, chemical and biological properties of soil. It affects are on moisture content, temperature, pH, organic matter, carbon, nitrogen, phosphorus, soil microbial activity, etc. of soil. It reduces 40% and 90% loss per annum in agricultural crops and forage crops, respectively. Although several workers have reported harmful effects of *Parthenium* on vegetation, crop plants, animals and human beings. However Shikha and Jha (2016 a, e, f, g, h, i) have evaluated the allelopathic effect of leaf extract of *Parthenium* on seed germination, seedling growth and seed vigour index in *Pisum sativum* (pea), *Cicer aeritinum* (gram), *Phaseolus mungo* (mung), *Cajanus cajan* (Arhar) and Zea mays. Parthenin is the active principal component among all the chemicals secreted by this plant which have the strong allelopathic and allergic effects.

(ii) Theories of Plant Invasion: Plant invasion is the most severe threat to biodiversity. Several hypotheses have been

proposed for weed invasions into grassland such as: (i)Theory of facilitation (Adkins and Sowerby 1996), (ii) Disturbance hypothesis (Adkins and Navie 2006), (iii) Theory of fluctuating resource avaibility (Allaie *et al*. 2006), (iv) Empty niche hypothesis (Anaya *et al*. 1990; Ayala *et al*. 1994), (v) Propagule pressure hypothesis (Bais *et al*. 2003; Bajwa *et al*. 2004), (vi) Novel weapons hypothesis (Bansal 1992), (vii) Enemy release hypothesis (Blossey and Notzold 1995), and (viii) Evolution of increased competitive ability hypothesis (Bruno *et al*. 2003). Callaway and Aschehoug (2000) while evaluating these hypotheses concluded that multiple factors lead to the success of invasive tree species like grass and animals. Callaway and Ridenour (2004) have reported that the following six hypotheses such as: (i) Biotic resistance hypothesis (Diversity- invisibility hypothesis), (ii) Island susceptibility hypothesis, (iii) Invasional meltdown hypothesis, (iv) Novel weapons hypothesis, (v) Enemy release hypothesis and (vi) Tens rule; only three hypotheses were supported by empirical tests (invasional meltdown 77%; Novel weapons; 74% and enemy release 54%). Callaway *et al*. (2004) while testing the novel weapons hypothesis concluded that invasive species may possess deterrent secondary chemistry but it is not a general pattern. Callaway *et al*. (2008) while supporting the novel weapon hypothesis experimentally explained that the invasive species release biochemicals that are novel and harmful to native plants by suppressing the local AM fungi of native plants. The invaders suppress naïve native mutualists and indirectly inhibit the native plants. They explained the novel weapon hypothesis in the context of invasive plants and arbuscular mycorrhizae.

Allelopathic Advantage against Resident Species (AARS) is extension of Novel weapon hypothesis which states that in invasive species higher concentrations of allelopathic, defence or antibiotic biochemical than in native species should be evolved (Daizy *et al*. 2002; Davis *et al*. 2000; Demissie *et al*. 2013; Devi *et al*. 2014 and Haselar 1976). Phytotoxins released from root and biochemicals present in leaves cause allelopathic effects (Hierror and Callaway 2003). Allelopathy is supported by many investigators as the success of invasive species (Holm *et al*. 1977 and Inderjit 1999).

(iii) Species Composition and Shoot Biomass: Shikha and Jha (2016 b) have recorded in J.P. University campus, Chapra, Bihar, India the species composition and production of shoot biomass of *Parthenium hysterophorus* L. invaded vegetation development in abandoned cropland. A total number of 13 herbaceous species were recorded. In addation to *Parthenium* other herbaceous plant species were *Dicanthium annulatum*, *Oxalis corniculata, Cynodon dactylon*, *Dactyloetenium aegyptium*, *Tridax procumbens, Cyperus rotandus, Digitaria setigera, Phyllanthus niruri, Eleusine indica, Evolvulus alsinoides, Croton sparsiflorus* and *Alysicarpus monolifer*. Phytosociological characteristics such as– frequency, density, abundance, live shoot biomass, relative frequency, relative density and relative dominance were determined quantitatively and qualitatively. *Parthenium* was the most dominant species having highest IVI values (106.29). The co-dominant species was *Dicanthium annulatum* (IVI= 45.68). Species richness, equitability and diversity values are lower than the values reported for tropical grassland vegetation of India. Shoot-biomass values were higher than the Indian grasslands. Thus, *Parthenium* showed aggressiveness and dominance in the newly developed vegetation. *Parthenium* affected the normal process of succession on abandoned agricuitural land by decreasing the species richness and plant diversity. Thus eradication of *Parthenium* is essential to accelerate the normal process of vegetation development and shoot biomas produced by *Parthenium* may be utilized in other beneficial purposes (Shikha and Jha 2016 b).

In *Parthenium hysterophorus* invaded vegetation developed after nine years of abandonment of cropland, shoot biomass production estimation study was conducted in Auguest 2015 (peak growth period) in about 240ha land of J.P.University Chapra campus (Shikha and Jha 2016 c). Altogether thirteen species were recorded including *P.hysterophorus*. The live shoot biomass value for *Parthenium* was 3205.32 gm^{-2} and for other species it ranged from 1 to 330.72 gm^{-2}. For other species minimum value $1gm^{-2}$ was for *Alysicarpus monolifer* and maximum value $330.72gm^{-2}$ for *Dicanthium annulatum.* Total shoot biomass value was 3992.24 gm^{-2}. *Parthenium* contributed about 80.3% of the total shoot biomass. About 0.78 $t.ha^{-1}$ yr-[1] shoot biomass was produced by *P.hysterophorus.* Alternatively the shoot biomass produced by *Parthenium* can be used as a raw material as feed, stock, forage, compost, green manure or as herbicide, pesticide, insecticide, ethanol, synthesis of nanoparticles, feed additive for silkworm, decolorizing agent etc. It can also be used in removal of basic dyes and production of rubber, paper and cardboards in industries. Thus, the alternative uses of *Parthenium* in beneficial purposes will be effective in management and eradication of *Parthenium* (Shikha and Jha 2016 c).

(B) Allelopathic Effects on Crops

(i) Soil and Crop Productivity: *Parthenium* is considered as the number one dangerous terrestrial weed because of its harmful effects on ecosystem, crops, animals and human beings. The productivity of crop is not only affected by *Parthenium* but animals, animal health, human beings and biodiversity of the ecosystems are also affected. Rashid *et al*. (2008) has reported inhibitory effect of aqueous extracts of *Parthenium* on seed germination and seedling growth in maize and barley, and 90% loss in the yield of sorghum (Tamado, 2000). Kanchan (1975) reported that toxins are released to the soil from *Parthenium* through leaching and decay which inhibit the branching and yield in tomato. Govindappa *et al*. (2005) recorded *Parthenium* as the secondary host of tomato leaf crul virus of tomato. Sukhada and Jayachandra (1979) also have reported that *Parthenium* supresses local vegetation by releasing the growth inhibitors through leaching, exudation of roots, decay of roots, decay of residues etc. Due to aggressive colonization of *Parthenium* many common medicinal plants in Pakistan are declining. Gnanaval *et al*. (2013) have reported 40% in loss in yield of crops and causing socio-economic impacts such as reduced economic returns to the farmers, reduction of crop yield, quality of harvest, increased cost of production, affecting cropping system, reducing crop diversification, reducing the value of croplands etc.

(ii) Effects of Leaf Extract on Seed Germination and Seedling Growth:

(a) *Phaseolus mungo* (Mung): Shikha and Jha (2016 a) have evaluated the effect of different concentrations of leaf extract of *Parthenium* hysterophorus L. on seed germination, seedling growth and fresh weight of *Phaseolus mungo*. The allelopathic effect of leaf extract of different

concentrations (2% , 4% , 6% , 8% , 10%) were compared with control treatment. After seven days of incubation at room temperature the aqueous leaf extract of *P. hysterophorus* on seed germination, root & shoot length, R/S ratio, Inhibition(-) or Stimulation(+) per cent, relation elongation of root & shoot and fresh weight of root & shoot of *P.mungo* have no significant inhibitory effect. This study disclosed that higher concentrations of leaf extract have irregularly affected the growth of *P. mungo* than lower concentrations. (Shikha and Jha 2016 a). The effect of leaf extract of *Parthenium* on seed germination and seedling growth on various cultivated and wild species are inhibitory but , An et al. (2005) reported the differences in susceptibility of different species towards the effect of allelochemicals . Thus the effect on seed germination and growth parameters of mung were erratic i.e. stimulatory on shoot length and inhibitory on root length (Shikha and Jha 2016 a).

(b) *Cicer aeritinum* (Gram): Shikha and Jha (2016 d) studied the allelopathic effect of aqueous leaf extract of *Parthenium hysterophorus* on seed germination, root & shoot length and fresh weight of root & shoot, root:shoot ratios, inhibition(-) or stimulation(+) %, relation elongation of root & shoot and seed vigour index(SVI) of *Cicer aeritinum L.*. The allelopathic effect of leaf extract of different concentrations (5%, 10%, 15%, 25%, and 50%) were compared with control treatment. Seed germination and growth performance of Chickpea were low at high concentrations of leaf extract except for shoot length and fresh weight of shoot. *P.hysterophorus* leaf extract particularly 10 to 50% inhibited the rate of seed germination of *C. aeritinum*. The higher concentration (50%) of leaf extract showed maximum inhibition in seed germination rate. It also inhibited the length of root but shoot length increased in higher concentration treatments. It clearly indicates that growth in root length and seed germination are more affected than the length of shoot in *C.aeritinum* by the allelopathic effect of leaf extract of *Parthenium* (Shikha and Jha 2016 d).

(c) *Pisum sativum* (Pea): Similarly the allelopathic activity of *Parthenium hysterophorus* L. leaf extract of different concentrations was studied on *Pisum sativum*. The allelopathic activity of leaf extract of different concentrations (5%, 10%, 15%,25%,50%) were compared to control condition. The higher concentrations of leaf extract reduced the rate of seed germination; and the length of root was inhibited in different treatments (63 to 77%) compared to control condition but the shoot length decreased from 2 to 45% only. The fresh weight of root except for 15% treatment and shoot, r:s ratios and SVI decreased compared to control treatment. The values for relative elongation ratios for root and shoot ranged from 23.09 to 37.67% and 55.54 to 98.34% , respectively (Shikha and Jha 2016 e).The inhibitory effect of aqueous leaf extract of *P.hysterophorus* on the rate of seed germination and length of root was more than the length of shoot of *P.sativum*. In general the fresh weight of root and shoot, root:shoot ratios and seed vigour index were affected by high concentrations of leaf extract of *Parthenium* .

(d) *Cajanus cajan* (Arhar): Shikha and Jha (2016 f) have reported that *Cajanus cajan* is an important pulse crop of India and *Parthenium hysterophorus* is an invasive weed of agroecosystem. The main aim of this study was to know the allelopathic effect is the main cause of success of *P.hysterophorus* in the fallowland which supports novel weapons hypothesis. Fresh leaves of *Parthenium hysterophorus* were collected, dried in laboratory and crushed to prepare powder. Different concentrations (15%, 25%, 50%, 75% and 100%) of leaf extract were prepared. In petridishes 10 seeds in triplicate were maintained with control condition of *Cajanus cajan*. After seven days per cent seed germination, length of root and shoot, R: S ratio, fresh weight of seedlings and seed vigour index (SVI), per cent inhibition in germination, root and shoot relation elongation ratios were determined. Standard errors were calculated, t-test and linear as well as multiple regression analyses were done. The effects on different parameters studied were more inhibitory for 100% treatment than the other treatments. The rate of seed germination in control was 96.67% whereas this value was 0.01% in 100% of leaf extract. However in other treatments these values ranged from 60% to 86.67%. The range of seed germination reduced from -10.34 to -62.07% in different concentrations of leaf extract of *P. hysterophorus*. The effect of different concentrations of leaf extract of *P. hysterophorus* on root length of *C. cajan* was more than the shoot length in the present study. In case of shoot length the values ranged from 9.05 to 4.41cm compared to control condition (8.26 cm) whereas in case of root length the values ranged from 5.11 to 1.16 cm in different treatments compared to control condition (3.92 cm). t-test and regression analysis indicated negative impacts of leaf extract of *P.hysterophorus* on *C.cajan*.This study indicated that the higher concentration of leaf extract of *P. hysterophorus* was more inhibitory than other treatments for *C. cajan*. The allelopathy is the main cause of invasion of *P.hysterophorus* that supports the novel weapons hypothesis. The negative impacts of leaf extract of *P.hysterophorus* on seed germination and seedling growth of *C.cajan* explains the allelochemicals secreated by *P.hysterophorus* as suggested by several workers regulate allelopathy. This supports the novel weapons hypothesis (Shikha and Jha 2016 f).

(iii) Effects of Stem Extract on Seed Germination and Seedling Growth:

(a) *Zea mays* (Maize): Shikha and Jha (2016 g) have studied the allelopathic effect of *P. hysterophorus* on the seed germination and seedling growth of maize (*Zea mays*) in laboratory conditions. The results showed that seeds were negatively affected by the aqueous stem extract of *Parthenium* in different concentrations (15%, 25%, 50%, 75% and 100%) when compared to control condition. The higher concentration ie. 100% of stem extract was more inhibitory for the seed germination and seedling growth. The rate of seed germination in control was 100% whereas this value was 3.33% in 100% of stem extract. The effect of different concentrations of stem extract of *P. hysterophorus* on shoot length was more affected than the root length in this study. The t-test, Linear regression equations and Correlation co-efficient values were calculated between shoot and root length and were compared with the values for control condition. t-teat values for root length between control and 50%, 75% and 100% were positively significantly related at $p<0.001$; and for shoot length these values for treatments were significantly at $p<0.001$. This study disclosed that higher concentrations of stem extract have adversely affected the growth of *Zea mays* than the lower concentrations. This study clearly indicated that the 100% stem aqueous extract concentration of *P. hysterophorus* was highly inhibitory against seed germination and seedling growth of *Zea mays*. Higher

concentrations were more inhibitory than lower concentrations. Root length is less affected than shoot length. Aqueous extract of stem of *Parthenium* inhibits more shoot than root in *Zea mays* (Shikha and Jha 2016 g).

(b) *Pisum sativum* (Pea): Shikha and Jha (2016 h) have evaluated the phytotoxic effect of *Parthenium hysterophorus* on seed germination, root length, shoot length and fresh weight of root & shoot of *Pisum sativum* under laboratory condition. Different levels of stem aqueous extract concentrations (15%, 25%, 50%, 75% and 100%) were used for this experiment. Higher concentrations of 75% and 100% aqueous extract of *Parthenium* drastically reduced the germination per cent of peas. The rate of seed germination varied from 46.67 to 100% in different concentrations of stem extract of *Parthenium* in pea being minimum (46.67%) for 100% treatment and maximum (100%) for 15% treatment whereas this value was 100% in control condition. SVI value ranged from 56.19 to 127.94 in comparison with control condition (197.21). Statistical analysis i.e. standard error, t-test, linear regression equations and correlation co-efficient values were calculated between root and shoot length and were compared with the values for control condition. t-test values for root length between control and 75% and 100% were highly significantly different ($p<0.001$) whereas other values were not significantly different and for shoot length all values were highly significantly different ($p<0.001$). The phytotoxicity of stem extract of *P.hysterophorus*are is the main cause of reduction in the rate of seed germination and seedling growth of *P. sativum*. Higher concentrations were more toxic to peas than lower concentrations of stem extract of *Parthenium*. The higher concentration (>50%) of stem extract of *Parthenium* decreased the rate of seed germination and length of root and shoot of peas. For shoot length higher concentration (100%) and for root length 50% concentration were most inhibitory. Shoot length was more affected than root length.Thus the stem extract of *Parthenium* is phytotoxic to the seed germination and seedling growth of peas. Stem extract is phytotoxic to peas and supports the novel weapons hypothesis. Thus for cultivation of peas in agricultural lands the eradication of *Parthenium* is essential because peas is the most important pulse of India (Shikha and Jha 2016 h).

(c) Effects on Animals: *Parthenium* is toxic to livestock, animals when it is consumed to repeatedly in contact with the weed. In addition those animals can encounter death, loss of skin pigmentations, allergic skin reactions, dermatitis, diarrhea, anorexia and pruritus. *Parthenium* can also affect the physiological behavior of animals. It also causes acute illness, when bitter and tainted meat from buffaloes, cows and goats, are fed on grass mixed with *Parthenium* (Shikha and Jha 2016 i).

(d) Effects on Human beings: It causes various types of allergies through pollengrains like: asthma, hay fever, rhinitis, dermatitis, eye irritation, skin rashes, peeling skin, puffy eye, excessive water loss, swelling and itching of mouth and nose and eczema.

Management of *Parthenium* weed

There are several methods available for controlling *Parthenium* weed. Some of the methods are: Physical, Chemical, Biological, Competitive replacement Utilization etc.

(a) Physical (Manual control) – Hand weeding, plouging, burning 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 pulling matured seeds will drop off and will increase the area of infestation. The second reason can be related to its effect on health. Ploughing can be considered as 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 (Musam *et al*. 2013).

(b) Chemical Control - Chemical control is an effective and quick way of controlling *Parthenium* weeds. There are many herbicides available in the market such as: buctril super, chwastox, chlorimuron ethyl, metasulphuron atrazine, dicamba, picloram, glyphosate, metribuzin, dicamba, picloram, glyphosate, metribuzin are to list some of them (Asad 2014). Most of them in any case are effective only on two leave plant. Glycel take 10/15 days to decay the plant. Post-emergence application (before flowering) of Mera 41@10 gms/L water. *Parthenium* is found mostly in no-man's land and use of chemicals in such areas need community efforts.

(c) Bioherbicidal control – The most challenging problem with synthetic herbicides is its toxicity or the problem it causes to the environment. This fact attracts the attention to replace synthetic herbicides. Some plants are known for their allelopathic nature and can be used as a potent herbicides 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* (Shazia *et al*. 2011), *Dicanthium annulatum, Sorghum halepense* (Arshad and Tehmina 2006), *Mangifera indica* L. (Arshad 2010), *Zingiber officinale*, *Allium cepa* L., *Allium sativum* L. (Shabnam *et al*. 2014), *Cymbopogon citrates*, *Eucalyptus citrodora*, *Cinnamomum camphora* (Singh *et al*. 2005), *Helianthus annus*, *Oryza sativa* (Arshad *et al*. 2008).

(d) Biological control – Biological control of *Parthenium* is the most economical environmentally safe as well as ecologically viable method. Several insect bio-control agents and fungal pathogen are currently in use in Australia against *Parthenium.* Management of *Parthenium* through biocontrol is considered as natural and self- sustaining. *Zygogramma bicolorata*, a Mexican beetle (50-100 beetles/plant) has been found promising. Mycoplasma- like organisms (MLO) could be utilized as they cause seed sterility. Some of the biocontrol agents utilized so far includes: *Epiblema strenuana* (stem-galling moth), *Zygogramma bicolorata* (leaf feeding beetles), *Carmenta ithacae* (root- boring moth), *Puccinia abrupt* (Winter rust fungus), and *Puccinia melampodii* (Summer rust fungus) (Bharat *et al*. 2011, Taye *et al*. 2004).

(e) 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, forage, herbicide, pesticide, insecticide, ethanol, compost, green manure, synthesis of nanoparticles, feed additive for silkworm, decoloriding agent can be listed among various uses of this plant (Jasvir 2013, Subhendu and Dinesh 2001, Khan *et al*. 2008 and Nisar *et al*. 2011). *Parthenium* can be managed by proper utilization such as herbicide, pesticide, insecticide raw material or as additive in paper; pulp, dye industries; as potent antioxidant, antimicrobial, anticancer etc.

(Tefera 2015). It can be used as a medicinal plant. Extract of *Parthenium* has been used in synthesis of silver nanoparticles by reducing silver ions of aqueous solution of silver nitrate complex (Parashar *et al*., 2009). Thus it can be used in nanotechnology based industries such as in bactericidal, wound healing and other medical and electronic applications. Other nano-particles can be synthesized by using this weed. Datta and Saxena (2001) have suggested that *Parthenium* can be used to increase the crop productivity by using the allelochemicals isolated from *Parthenium* as herbicides, insecticides, nematicides, fungicides, growth regulator, ovicidal and antifleedant; and also as defence against herbivorous predators. *Parthenium* can be exploited for industrial pollution control. Lata *et al*. (2008) have reported that sulphuric acid treated carbonized *Parthenium* (SWC) will be an effective, easily available and low cost adsorbent for removal of Ni (II) from dilute aqueous solution of effluents of silver refineries, electroplating, Zinc based casting and storage battery industries. Nickel causes cancer of lungs, nose and bone. Thus from the Nickel contaminated waste water nickel can be adsorbed and removed by using *Parthenium.*

Ajmal *et al*. (2006) have used the dried powder of *Parthenium* as an adsorbent for Cd(II) from waste water by applying the batch process and reported maximum adsorption of Cd(II) ions in pH range 3-4 as 99.7%. Cd is used in electroplating, plastic manufacturing, metallurgical processes, pigment industries and Cd/Ni batteries. Cd is toxic in low dosages and causes renal disorder, high blood pressure, bone deformity and distruction of RBCs. Singh *et al*. (2008) have compared the commercial grade activated carbon (AC) with *Parthenium* based activated carbon (PAC) as effective adsorbent material for removal of cresol and it was reported that PAC was as good as AC upto 500mg/l in aqueous solution, cresol is found in effluents of petrochemical, oil and metal refineries, chemical and glass fibre manufacturing, ceramic and steel plants, phenolic resin manufacturing industries etc; and cresol causes stomach tumors, corrode the eyes, skin and respiratory tracts and affects the central nervous system, cardiovascular system, lungs, kidney and liver, leading to unconsciousness and death. The sulphuric acid-treated *Parthenium* and phosphoric acid-treated *Parthenium* can be considered as potential adsorbents for methylene blue removal from dilute solutions (Lata *et al*. 2007). The dry leaf powder of *Parthenium* can be used to cause wilting and desication of above water parts of floating plants which choke off water bodies such as in *Salvinia*, *Pistia* and *Eichhornia* (Pandey 1994). A large number of bioactive compounds such as sesquiterpene lactones, flavanoides, glycosides and pinenes are present in *P.hysterophorus* which have multiple pharmacologic properties such as anticancer, anti-inflammatory, cardiotomic, antispasmodic, an emmenagogue and as an anema for worms. According to Bhatt *et al*. (2012) high humidity, high moisture content and temperature around 25^0 C are suitable conditions for seed germination in *Parthenium* and it has been included in the Global Invasive Species database of IUCN due to its invasive nature. The severity of the *Parthenium* weed problem has compelled researchers and people from various action group and societies to provide a forum for those is need and affected by *Parthenium* weed.

Chemicals isolated from *Parthenium* shows following Pharmacological Actions:

- Anti inflammatory
- Antioxidant activity
- Anticancer and cytotoxic activity
- Antimicrobial activity
- Pesticidial
- Wound healing
- Hypoglycermic activity
- Thrombolytic activity
- Preventation and Treatment of Migrane
- Rheumatoid Arthritis
- Economic Importance

Thus if the above ground biomass (shoot biomass) produced by *Parthenium* is used properly in the important purposes for human beings, it will be a boon for the society in near future (Shikha and Jha, 2016 j)

Conclusion

The spread of *Parthenium* in India is at a speedy rate. It affects the natural vegetation, crops, live stock, human beings and the environment as a whole. In the case studies for evaluation of allelopathic effects of aquous extract of leaf and stem we have recorded that it is species specific. Some crops are more sensitive to allelopathy than other species. There is also significant differences on the growth of root and shoot of different crops. An integrated management system is to be developed for the control and eradication of *Parthenium* in India. If we use *Parthenium* for useful purposes as an alternative method of control it will be a boon for the society.

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