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Review article

Parthenium hysterophorus L., a noxious invasive weed

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Abstracts

Parthenium hysterophorus L., a member of the family Asteraceae and native to subtropics of North and South America, is an invasive plant species that colonizes disturbed areas, cultivated lands, roadside vegetation, and human settlement areas. The weed has prolific seed producing ability and fast spreading in nature. The plant is rapidly infesting into tropical and subtropical regions of the world. Its occurrence in Kathmandu valley was reported first time in 1986. The seeds are highly viable and adaptive and can travel long distance with the help of its wing like structures at the base. They can anchor on rough surfaces with the help of feathered claws like structures. The weed is being very problematic because of its aggressiveness, allelopathic impacts, and health hazard risks for human and livestock. The weed posses different allelochemicals, specially sesquiterpenes and phenolics, parthenin being the chief one. The weed adversely affects crop plants and sensitive grass species. Besides it causes hay fever, dermatitis, skin infections, bronchitis and several other health impacts. The control of the weed is a challenging task; however, different herbicides and some biological agents have been reported for its management.

Key words: allelochemicals, allelopathy, health hazard, Nepal, parthenin, sesquiterpene.

Introduction

Parthenium hysterophorus L. (family: Asteraceae) is an annual weed known with various common names, such as false ragweed, star weed, bitter weed, white top, bastard feverfew etc. and is found in tropical and subtropical regions (Tiwari *et al*. 2005). It is native to the subtropics of North and South America. The weed is now widely distributed in a number of tropical and subtropical countries, like Australia, India, China, and Kenya (Navie *et al*. 1996; QNRM 2004). It was introduced to Australia only 50 years ago (CRC 2003). First occurrence of the weed in Nepal was reported by Malla from Trishuli in 1967 (Tiwari *et al*. 2005). A report suggested that the weed has been finding its place in Kathmandu valley since 1986 (Mishra 1991; Adhikari and Tiwari 2004).

Parthenium hysterophorus (hereafter referred to as *Parthenium*) is considered as an invasive weed because of its prolific seed production capacity, fast spreading ability and strong competitiveness (Haseler 1976; Tamado *et al*. 2002). The plant is hazardous to the health of human (Khosla and Sobti 1981) as well as other animals (Chippendale and Panetta 1994). The weed is reported to have allelopathic impacts on different plants. Biochemical studies suggested the presence of an active chemical parthenin, a sesquiterpene lactone, which is responsible for allergic reactions and strong allelopathic effect (Bhowmik *et al*. 2007). The chemicals released from the plant inhibit seed germination and growth of pasture grasses, legumes, cereals, vegetables, other weeds, and even trees (ARMC 2000). Plant residues in soil create problem in pasture establishment (QNRM 2004). The weed causes heavy loss with estimated cost $ 16 million per year in Australia (ARMC 2000). This problematic weed, however, is reported to be replaced effectively by *Cassia uniflora* - a leguminous undershrub found in some parts of Karnataka and Maharashtra states of India (Joshi 1991).

The weed is reported as a good source of biogas and also can be used as green manure and whole plant extracts can be used as flea repellant and herbicide (ARMC 2000). In addition, its pesticidal potential has been established in terms of ovicidal, anti-fleedant, and nematocidal effects (Datta and Saxena 2001). Despite of being toxic, its industrial uses are also accountable. Interestingly, its medicinal properties have been reported as a remedy for hepatic amoebiasis (Sharma and Bhutani 1988). The weed has also been used as folk medicines in the Caribbean and Central America (Navie *et al*. 1996). The weed, however, has not been used for any purpose in Nepal (Tiwari *et al*. 2005) and its control measure is being equally emphasized but the effective way is still lacking.

The main objective of this paper is to introduce and raise the general awareness of the weed *Parthenium* focusing on its status, and possible hazards to human, cattle and vegetation. It also focuses on different control measures and their effectiveness in the management of the weed.

Description of the Plant

MORPHOLOGY

Parthenium (Fig. 1) is a much branched annual or short-lived ephemeral herb, growing to two meters under favorable conditions. Under dry conditions the plant may mature and set seed at the height of only 10 cm. The leaves are grayish-green, 30-60 mm, deeply lobed, pubescent. Stems are hard, woody (solid) and are covered

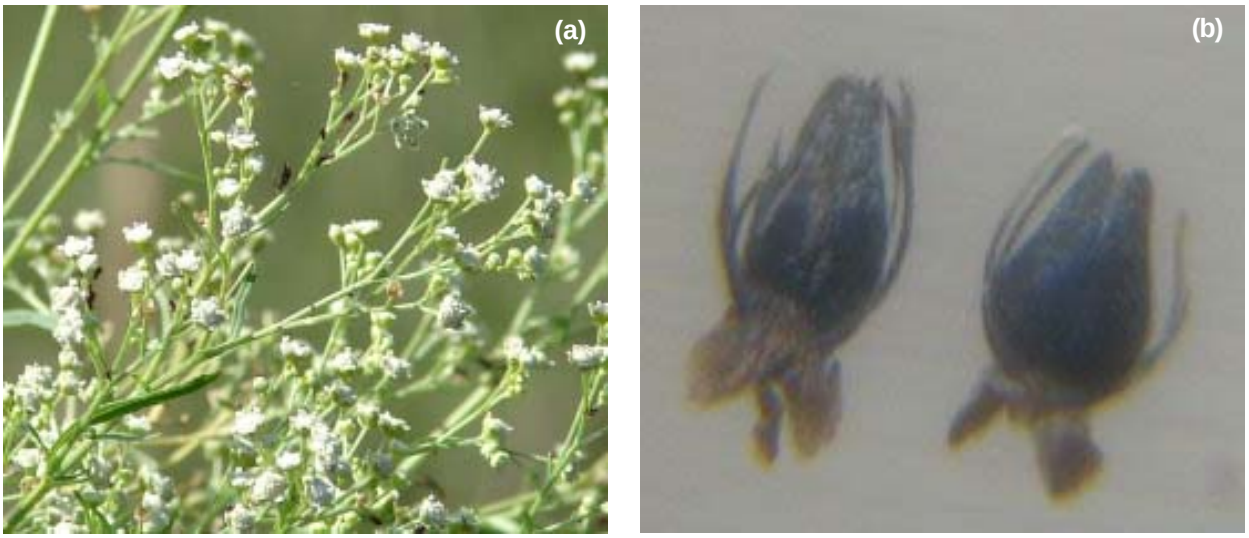

Fig. 1. *Parthenium hysterrophorus* L. (a) flowering branch, (b) seeds (enlarged).

with small hairs. Flowers are creamy-white of about 4 mm in diameter that are borne in clusters terminally on the branches. Each flower head produces about four seeds that are black in color ranging 1-1.5 mm in length (QNRM 2004) with two lateral feathered appendages each on either side. Fruits are one-seeded achenes.

OCCURRENCE

Parthenium is an aggressive colonizer of areas of poor ground cover and exposed soil, such as roadsides, overgrazed pastures, wastelands, cultivated lands as well as fallow lands and settlement areas (Tiwari *et al*. 2005). It is not usually established in undisturbed habitat. Therefore, there is a marked inverse relationship between existing plant cover and weed density (QNRM 2004). The size and persistence of soil seed bank, longevity of buried seeds, fast germination rate, and inherent seed dormancy make it well adapted to semi-arid environment (QNRM 2004).

LIFE CYCLE

Parthenium does not reproduce vegetatively, the only method of reproduction and dispersal is by seed (Fig. 2). It can produce large amount of seeds (up to 100,000 per plant) (CRC 2003). More than 340 million seeds per hectare can be present in the soil surface (CRC 2003). The seeds can be easily spread by vehicles, machinery, animals, and water. Local dispersal of the achenes occurs by wind and water, while long dispersal is mainly by motor vehicles, machinery, and livestock movement (Auld *et al*. 1983). A period of drought followed by rain provides ideal conditions for seed dispersal. Drought reduces pasture cover (competition) and increases movement of livestock (QNRM 2004).

In summer, plants can flower and set seed four weeks after germination. Buried seeds last longer than the seeds on the soil surface. The seed viability was reported to be greater than 50% after 26 months of burial in the soil indicating the potential build-up of a substantial persistent soil seed bank (CRC 2003). However, unlike other weed species, there is no critical point where intervention is required, as *Parthenium* can produce flowers and seeds at any time of the year under favorable conditions. The flower lasts for 2-3 months, unless curtailed by frost and drought (Nath 1988).

Seed germination depends on high moisture but is inhibited by shading, plant competition or burial. Most germination occurs in spring to early summer. The optimum temperature for seed germination is 10-25^{0}C (Tamado and Milberg 2000). However, the seed germination is reduced significantly at 5-11^{0}C (Williams and Grooves 1980). *Parthenium* may increase seed survival by discouraging decay and predation of seeds. Although, larger-sized seeds give higher germination percentage in comparison to the smaller ones (Pandey and Dubey 1988), *Parthenium* growing on coarse textured soil produces a large number of light seeds which facilitates colonization on new areas (Anapurna and Singh 2003). After 1-2 week(s), seedling growth takes place, which is fast in spring/summer and slow in winter. The mature plant will arise within/after one week of germination. First flower bud initiation to produce mature inflorescence and dispersal of the first achene is 30 days; while it takes just 14 days time to produce mature achenes after pollination (Lewis *et al*. 1988). It is estimated that a single plant can produce 25,000 or more achenes with numerous seeds and therefore has prolific seed production capacity (Haseler 1976; Joshi 1991).

Harmful Effects

Parthenium is experienced as harmful to humans, cattle and other neighboring plant species. Different studies are being made in its harmful aspects especially for biodiversity, its allelopathic behavior, impact on human health, impact to animal husbandry, etc.

ALLELOPATHY AND BIODIVERSITY

Allelopathy is the phenomenon in which living or dead plant materials, including decaying litter, releases chemicals that inhibit

(rarely stimulates) the growth of associated plants (Rice 1984). Allelopathic interference is one of the important mechanisms for the successful establishment of exotic weeds (Ridenour and Callway 2001), but this lacks empiric evidences (Prati and Bossdorf 2004). Allelopathic interference has also been well explained in the weed *Parthenium*. Almost all the parts of the weed including trichomes and pollen grains are allelopathic (Kohli and Rani 1994; Evans 1997). The roots and shoot extracts of the weed posses some growth inhibitors which suppress or inhibit the growth of sensitive neighboring plant species.

A number of water soluble compounds of allelopathic nature, including phenolics and sesquiterpene lactones, have been identified in the plant and are implicated in allelopathic experiments (Kanchan 1975; Picman and Picman 1984). Sesquiterpene lactones constitute a large group of compounds exhibiting diverse biological activity (Fischer *et al*, 1994). These are active at very low concentrations and shows specific structure-activity relationship (Beekman *et al*. 1997). Some of the important chemicals of the group sesquiterpene lactones are: parthenin, cronopilin, 2-*â*-hydroxy cronopilin, tetraneurine A, hysterones A-D, etc. (Ramesh *et al*. 2003). Still, other phenolic compounds isolated from the plant are caffeic acid, vanilic acid, p-coumeric acid, anisic acid, feulic acid and chlorogenic acid (Rajan 1973; Mersie and Singh 1988). Further, chaminarone is another compound of the groupseco-pseudoguinaloides reported from the weed (Venkataiah *et al*. 2003).

These inhibitors are released in soil through root exudation, residue decay and leaching (Mersie and Singh 1988). The leaf extracts from the weed shows varying degree of allelopathic impact on economically important crops, like *Raphanus sativus*, *Oryza sativa*, *Zea mays*, *Triticum aestivum*, *Brassica oleracea*, etc. (Maharjan *et al*. 2007). The flower and leaf residue of *Parthenium* were reported to have lethal effect to aquatic plants, like *Salvinia* (Pandey 1994), *Najas* (Pandey 1997) and water hycianth (Pandey 1996). Extracts prepared from burnt and unburnt residues of *Parthenium* reduces seedling length and dry weight of crop plants such as radish and chick pea, although burnt residue extracts were found more phytotoxic than unburnt residue (Singh *et al*. 2003). Likewise, the diffusates from plant and germinating seeds of *Parthenium* can arrest glucose production in germinating seeds of *Raphanus sativus* (Paudel *et al*. 2009).

Parthenin, an allelochemical from the weed, has adverse impact on protein and carbohydrate metabolism (Singh *et al*. 2002). Srivastava *et al*. (1985) reported that aqueous extracts of leaves and inflorescence of the weed inhibited the germination and seedling growth of barley, wheat and peas but the extracts from roots and stems were less inhibitory (Kohli *et al*. 1985). Parthenin is also found to be toxic causing adverse effects on seedling growth of wheat (Patil and Hedge 1988). Significant reduction in plumule and radical growth of *Pennisetum americanum* by parthenin was reported by Valliappan and Towers (1989). Similar allelopathic effects have been shown with foliar leachates of *Parthenium* on a diverse range of agricultural plants and tree crops: cow pea, sunflower, *Casuarina*, *Acacia*, *Eucalyptus* and *Leucaena* (Swaminathan *et al*. 1990); rice, wheat, black gram and chick pea (Singh and Sangeeta 1991); frenchbean, cotton and sunflower (Madhu *et al*. 1995); sorghum (Ayla *et al*. 1994); and spinach (Gupta 1996).

Kohli and Batish (1994) have found reduced germination and yield of black and green gram when these were grown in soils previously infested by *Parthenium* weeds. Aqueous solutions from different parts of the weed are found to be much effective to arrest the seed germination of some plants, like *Eragrotis tef* (Tefera 2002). Recently, Belz *et al*. (2007) investigated the level of involvement of parthenin in overall phytotoxicity of decomposing leaf material in a South African population of *Parthenium hysterophorus*. Results showed that the contribution of parthenin is highly dependent on its concentration inextract solutions and varied between 16% and 100% of overall phytotoxicity of leaf extracts. Besides, parthenin treatments are proven to delay germination and stimulate root growth at low doses in various experiments.

Because of its invasive nature and allelopathic behavior, the weed has the potential to disturb and disrupt natural ecosystems. The successful establishment of the weed in an ecosystem is attributed to its high reproductive potential, fast growth rate, adaptability and allelopathic effects (Adkins and Sowrby1996; Kohli and Rani 1994). The weed is attributed to be mainly responsible for causing total habitat change in native Australian grasslands, river banks and flood plains (McFadyen 1992; Chippendale and Panetta 1994). Similar invasions in most of the places of Kathmandu valley and Chitwan district have been observed in Nepal (author's personal observation). A number of aquatic plants are affected by the allelochemicals produced by *Parthenium* (Pandey 1994, 1996, 1997) which may have adverse effects on aquatic exosystem.

EFFECTS ON PESTS

Parthenium is potential in alteration of several hosts for crop pests. For example, it causes alteration of the plant parasitic nematodes in USA (Navie *et al*. 1996). Different pest species of the groups Coleoptera, Homoptera and Lepidoptera are important in both agriculture and forestry and it has been recommended that such insects could be exploited for biological control of the weed *Parthenium* (Evans 1997; Navie *et al*. 1996).

DISEASE VECTOR

The weed *Parthenium* is also explained as the vector of different plant pathogens. The weed is supposed to be natural host and reservoir of potato virus X and Y (Cordero 1983). The weed acts as secondary host for different plant diseases. In Cuba, the bacterial pathogen *Xanthomonas campestris* pv. *phaseoli* is suspected to be transmitted from this weed to *Phaseolus vulgaris* with reciprocal infection at the pre-flowering and pod formation stages (Ovies and Larringa 1988). The notorious bacterial wilt pathogen *Pseudomonas*

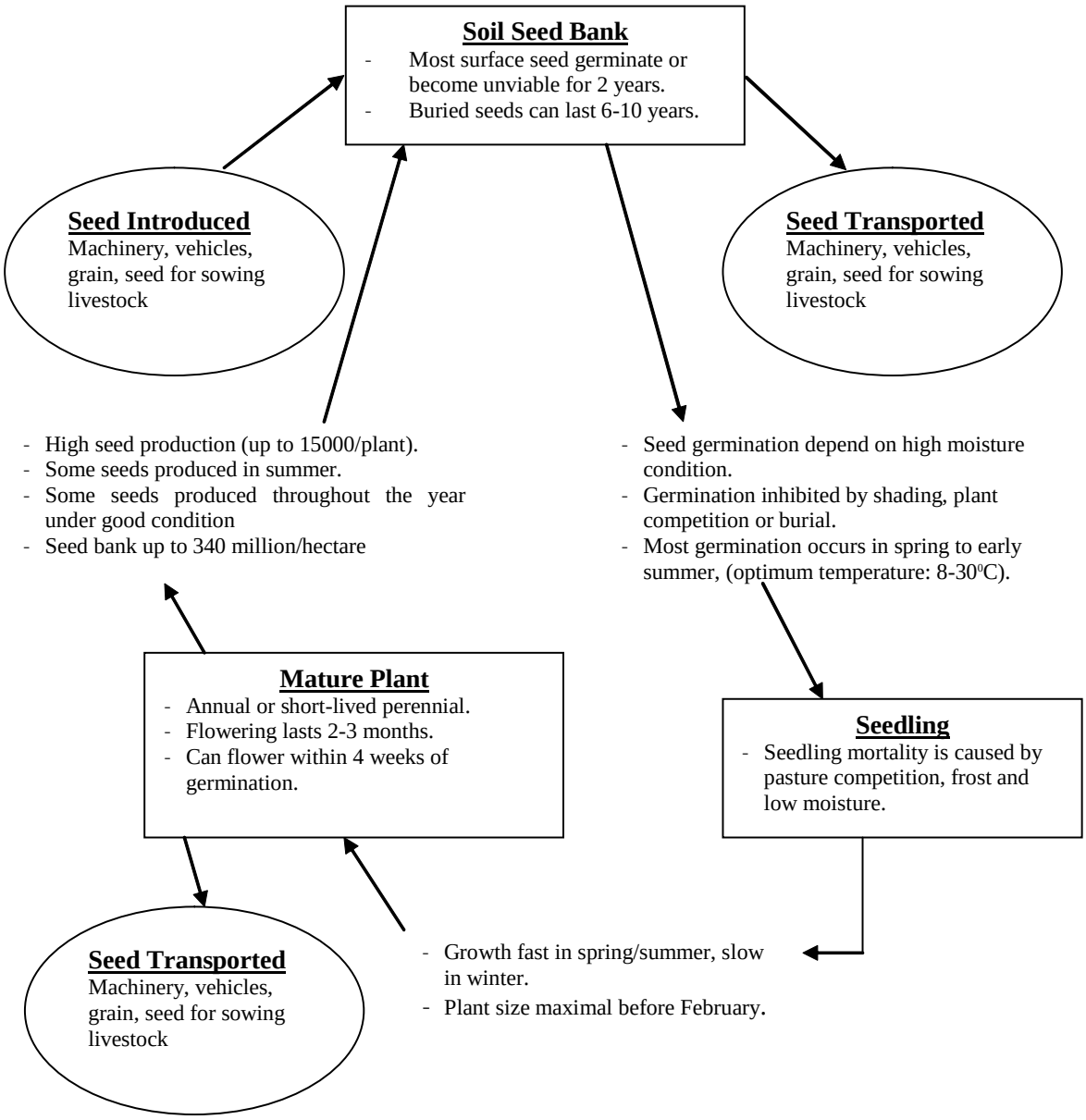

Fig. 2. Life cycle of *Parthenium* weed (CRC 2003).

solanacearum has also been recorded on *Parthenium* weed (Kishun and Chand 1988). Besides, 'tomato leaf curl virus' is also in report to be transmitted from the weed (Sastry 1984).

IMPACTS ON HUMAN HEALTH

Some serious health risks were reported to be caused by *Parthenium* more than two decades ago from India (Lonkar *et al*. 1974). Regular contact with the plant or its pollen could cause dermatitis, hay fever, and even asthma, bronchitis and respiratory tract infections in humans (McFadyen 1995; Evans 1997; Bhowmik *et al*. 2007). Tanner and Mattocks (1987) highlighted that the hepatotoxic parthenin reacts synergistically with copper in causing Indian childhood cirrhosis (ICC). At present, there are innumerable diseases reported to be caused by the weed *Parthenium* which has no remedy other than moving away from the weed infested area.

ANIMAL HUSBANDRY

Parthenium has both direct and indirect effects on animal health, deteriorating milk and meat quality. Narasimhan *et al*. (1977) reported that cattle and buffalo feed it sparingly while goats graze it readily. It can cause death of livestock if consumed in significant amount (CRC 2003). The majority of animals developed dermatitis and toxic symptoms and died within 8-30 days. Lesions were also reported from gastrointestinal tracts, liver and kidneys (Ahmed *et al*. 1988; Kadhane *et al*. 1992). Chippendale and Panetta (1994) conducted a

survey of beef producers in heavily infested areas in Central Queensland and reported that *Parthenium* could completely dominate grazing land, resulting in weed monocultures and reduced stocking rates up to 80% (McFadyen1992).

Beneficial use

The whole plant of *Parthenium* can be used as green manure, its extracts as herbicides and flea-repellant (Navie *et al*. 1996). Antitumor and antiamoebiatic activities have been reported in the weed (Mew *et al*. 1982; Sharma and Bhutani 1988). In addition, *Parthenium* is the valuable source of potash, oxalic acids and high quality protein (HQP) which can be used in animal feed (Mane *et al*. 1986; Savangikar and Joshi 1978). Different studies revealed the pronounced use of the weed as a source of biogas. The weed was also used in a folk medicine in the Caribbean and Central America (Navie *et al*. 1996).

Control measures

The control of *Parthenium* weed is being a serious challenge due to its vigorously spreading nature. Immediate actions are being quite necessary to eradicate the plant since it has more hazardous impacts on environment as well as in public health. Nepal has great risk of rapid invasion of the weed in agricultural lands, for which it might have to pay a lot if proper attention is not paid towards its control measures. Many researches are going on for finding the cheap and best way for its control. Some of the control measures that can be undertaken in Nepal are as follows (In reference of ARMC 2000; QNRM 2004; CRC 2003):

PASTURE MANAGEMENT

Grazing management is the most useful method of controlling *Parthenium* spread in a large scale. However, this practice has not been implemented effectively in Nepal. Pasture land can be maintained in good condition with high levels of ground and grass crown cover. This may however, requires rehabilitation of poor pastures followed by sound grazing maintenance program. Such a practice, however, has a lot of challenges in Nepal due to socio-economic and cultural factors.

CONTROLING OVERGRAZING

Overgrazing may increase the *Parthenium* infestation. Control of overgrazing therefore can minimize its infestation to some extent. High grazing pressure caused by high stock numbers decreases the vigor and competitiveness of pastures that allow the spread of *Parthenium* weed. So maintenance of correct stock number might be fruitful in the control of *Parthenium* weed dispersal. Alternatively, pasture spelling can be helpful for rehabilitation of pasture lands which might be more effective than simply reducing the stocking rate. However, overgrazing must be avoided. Spring-summer period is found to be quite suitable for pasture spelling with first 6-8 weeks being quite important (QNRM 2004). Grazing during winter is generally safe since the period has low risk of *Parthenium* spread. Most tropical grasses are dormant and can tolerate moderate grazing during this period. However, *Parthenium* may grow and germinate in this time also.

BURNING

Another commonly practiced way of controlling *Parthenium* weed is burning. Mass vegetation of the weed can be destroyed by this practice. But burning is not promoted as a control strategy for the weed since there is great risk to soil, air and existing plant and animal diversity.

HERBICIDE CONTROL

Non-cropping areas

Parthenium should be eradicated by herbicide treatment early before it can set seed. Small and isolated areas of infestations can be treated immediately. Repeated spraying is necessary within one growing season to prevent further seed production. Spraying should be done before the flowering when the plant is small. Active growth of other grasses could be prompted for simultaneous control of the weed. Some of registered herbicides to control *Parthenium* weed are: atrazine, 2, 4-D+picloram (trodon 75-D) 2,4-D ester, glyphosate, metasulfuron methyl (for seedlings only), hexazinone, dicomba, etc (CRC 2003). These herbicides in different concentrations are effective for spot spray or boom spray or both (CRC 2003).

Cropping areas

Use of herbicide in cropping areas is a little bit risky since it might have adverse effect on growing crops. Controlling *Parthenium* weed in cropland requires selective herbicide use and/or crop rotations. The biological or natural herbicides, like the volatile oils from aromatic plants in very low concentration are quite helpful on such areas to abort *Parthenium* seeds (Paudel and Gupta 2008; Singh *et al*. 2005). These essential oils have no or little effect on the existing vegetation/crops (Isman 2000). Investigations have proven that the volatile oil from *Eucalyptus* sp., at certain concentration, can bring about adverse physiological effect on seed germination of *Parthenium* (ARMC 2000).

BIOLOGICAL CONTROL

Biological control might be one of the best methods for controlling the *Parthenium* weed dispersal. Many species of insects and two rust pathogens have been introduced to control *Parthenium*. The moth *Epiblema strenuana* (introduced form Mexico) has been established in all *Parthenium* dominated areas (CRC 2003). The moth's larvae feed inside the stem, forming galls which inhibit the plant growth (CRC 2003). Some other released insects which are found to be beneficial in controlling the weed are summarized in Table 1.

Table 1. Insects and their effects on *Parthenium* weed (QNRM 2004).

Name of the insect	Common name	Introduced from	Effect
Listoronotus setosipennis	Steem-boring weevil	Argentina	Bores stem of the weed
Zygograma bicolorata	Defoliating beetle	Mexico	Defoliation
Smicronyx lutulentus	-	Mexico	Lay eggs in the flower buds where the larvae feed on the seed head
Conotrachelus albocinereus	Stem-gulling weevil	Argentina	Produces stem galls
Bucculatrix parthenica	Leaf mining moth	Mexico	Larvae feed on leaves, leaving clear windows in the leaf
Carmentia ithacae	Stem boring moth	Mexico	Bores stem of the weed
Epiblema strenuana	Gall forming moth	Mexico	Induces galls in the weed

Besides, two more species of insects, namely *Stobaera concinna* and *Platplhalonidia mystica*, are also effective in controlling the weed (Navie *et al*. 1996). Further, two fungal diseases (rusts) that are found to be effective for controlling *Parthenium* are: *Puccinia abrupt* and *Puccinia melampodii* (respectively winter and summer rust of the weed) (CRC 2003; QNRM 2004). The former rust species is reported to infect and damage the leaves and stems (at $<16^0$C and 5-6 hrs of wetness), while the later species weakens the plant by damaging the leaves over the summer growing season (CRC 2003; QNRM 2004). As a combined effect the biological control agents can reduce the density and vigor of *Parthenium* weed and increase grass production (CRC 2003).

MANUAL CONTROL

Manually, *Parthenium* weed can be controlled by simple hand plucking. But this is not recommended since it might cause serious health hazard. Further, the seeds may drop off and increase the area of infestation.

CONTROL BY OVER USE OF THE WEED

Parthenium can be kept under control by enhancing its use in different aspects. It can be extensively used for biogas production, as green manure and flea-repellant and herbicide. Over-exploitation of the weed for its beneficial use thus should be prompted in the developing countries like Nepal where implementation of other alternatives and expensive control measures is difficult.

Conclusion

Parthenium hysterophorus growing on roadsides, disturbed areas, and fallow and cultivated lands is being a very common weed now--days. It's fast growing ability, heavily infesting nature, strong competitiveness and allelopathic effects not only disturbs the growth and development of other plant species but also can alter the vegetation pattern where it grows. Equally, it is very hazardous to human and cattle affecting the milk quality, meat quality and causing several diseases to human and cattle. Besides, the possibility of its impact on agricultural crops can not be overruled. Therefore, the weed is related somehow with the socio-economic conditions of the people in Nepal. Use of herbicides, essential oils from aromatic plants, and several bio-control measures however can be fruitful for its control. The concerned authority has to pay a proper attention on time for its control and management and sufficient researches have to be carried out in this line.

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References

Adhikari B. and Tiwari S. 2004. *Parthenium hysterophorus* L.: highly allergic invasive alien plant grown tremendously in Nepal. *Botanica Orientalis* 4: 36–37.

Adkins S.W. and Sowerby M.S. 1996. Allelopathic potential of the weed, *Parthenium hysterophorus* L. in Australia. *Plant Protection Quarterly* 11: 20–23.

ARMC (Agriculture and Resource Management Council of Australia and New Zealand) 2000. *Weeds of National Significance. Parthenium Weed (*Parthenium hysterophorus*) Strategic Plan*. National Weeds Strategy Executive Committee, Australian and New Zealand Environment and Conservation Council and Forestry Ministers, Launceston, Australia.

Ahmed M.N., Rao P.R. and Mahender M. 1988. Hematological observations in experimental partheniosis in buffalo calves. *Indian Veterenary Journal* 65: 972–974.

Annapurna C. and Singh J.S. 2003. Phenotypic plasticity and plant invasiveness: case study of cingress grass. *Current Science* 85(2): 197–201.

Auld B.A., Hosking J. and McFadyen R.E. 1983. Analysis of the spread of tiger pear and *Parthenium* weed in Australia. *Australian Weeds* 2: 56–60.

Ayla J.R., Cruz A.M. and Miranda Z. 1994. Effects of the aqueous extract of *Canavalia ensiformis, Bursera graveolens, Petiveriaallicea* and *Parthenium hysterophorus* on sorghum germination. *Cuban Journal of Agricultural Sciences* 28: 371–373.

Beekman A.C., Woerdenbag H.J., Uden W.V., Pras N. and Schmidt T.J. 1997. Structure-cytotoxicity relationship of some phelenanolide-type sesquiterpene lactones. *Journal of Natural Product* 60: 252–257.

Belz R.G., Reinhardt C.F., Foxcroft L.C. and Hurle K. 2007. Residue allelopathy in *Parthenium hysterophorus* L.: does parthenin play a leading role? *Crop Protection* 26(3): 237–245.

Bhowmik P.C., Sarkar D. and Yaduraju N.T. 2007. The status of *Parthenium hysterophorus* and its potential management. *Ecoprint* 14: 1–17.

Chippendale J.F. and Panetta F.D. 1994. The cost of parthenium weed to the Queensland cattle industry. *Plant Protection Quarterly* 9: 73–76.

Cordero M. 1983. *Parthenium hysterophorus* (escoba amarga), planta indeseable, reservorio natural de los virus X y Y de la papa. *Cinecia Tecnica en la Agricultura* 2: 23–32. (in Spanish).

CRC 2003. *Weed Management Guide*: *Parthenium Weed* (Parthenium hysterophorus). The state of Queensland, Department of Natural Resource and Mines, Queensland Government, Queensland, Australia.

Datta S. and Saxena D.B. 2001. Pesticidal properties of parthenin (from *Parthenium hysterophorus*) and related compounds. *Pest Management Science* 57: 95–101.

Evans H.C. 1997. *Parthenium hysterophorus*: a review of its weed status and the possibilities for biological control. *Biocontrol News and Information* 18: 89–98.

Fischer N.H., Williamson G.B., Weidenhamer J.D. and Richardson D.R. 1994. In search of allelopathy in Florida scrub: the role of terpenoides. *Journal of Chemical Ecology* 20: 1355–1379.

Gupta A. 1996. Allelopathic influence of *Parthenium hysterophorus* L. over *Amaranthus gangeticus*. *Flora and Fauna* 2: 57–58.

Haseler W.H. 1976. *Parthenium hysterophorus* L. in Australia. *Pest Articles and News Summaries* (*PANS*) 22: 515–517.

Isman M.B. 2000. Plant essential oils for pest and disease management. *Crop Protection* 19: 603–608.

Joshi S.S. 1991. Interference effects of *Cassia uniflora* Mill on *Parthenium hysterophorus* L. *Plant and Soil* 132: 213–218.

Kadhane D.L., Jangde C.R., Sudekar R.D. and Joshirao M.K. 1992. *Parthenium* toxicity in buffalo calves. *Journal of Soils and Crops* 2: 69–71.

Kanchan S.D. 1975. Growth inhibitors from *Parthenium hysterophorus* L. *Current Science* 44: 358–359.

Khosla S.N. and Sobti S.N. 1981. Effective control of *Parthenium hysterophorus* L. *Pesticides* 15: 18–19.

Kishun R. and Chand R. 1988. New collateral hosts for *Pseudomonas solanacearum*. *Indian Journal of Mycology and Plant Pathology* 17: 237.

Kohli R.K. and Batish D.R. 1994. Exhibition of allelopathy by *Parthenium hysterophorus* L. in agrosystems. *Tropical Ecology* 35: 295–307.

Kohli R.K. and Rani D. 1994. *Parthenium hysterophorus* – a review. *Research Bulletin (Science) of Panjab University* 44: 105–149.

Kohli R.K., Kumari A. and Saxena D.B. 1985. Auto- and tele-toxicity of *Parthenium hysterophorus* L. *Acta Universitatis Agriculturae Brno* (Czechoslovakia) 33: 253–263.

Lewis W.H., Dixit A.B. and Wender H.J. 1988. Reproductive biology of *Parthenium hysterophorus* (Asteraceae). *Journal of Palynology* 23-24: 73–82.

Lonkar A., Mitchell J.C. and Calnan C.B. 1974. Contact dermatitis from *Parthenium hysterophorus*. *Transactions of the St. John's Dermatological Society* 60: 43–53.

Madhu M. Nanjappa H.V. and Ramachandrappa B.K. 1995. Allelopathic effect of weeds on crops. *Mysore Journal of Agricultural Sciences* 29: 106–112.

Maharjan S., Shrestha B. and Jha P.K. 2007. Allelopathic effects of aqueous extracts of leaves of *Parthenium hysterophorus* L. on seed germination and seedling growth of some cultivated and wild herbaceous species. *Scientific World* 5: 33–39.

Mane J.D., Jadav S.J. and Ramaiah N.A. 1986. Production of oxalic acid from dry powder of *Parthenium hysterophorus* L. *Journals of Agriculture and Food Chemistry* 34: 989–990.

McFadyen R.E. 1995. Parthenium weed and human health in Queensland. *Australian Family Physician* 24: 1455–1459.

McFadyen R.E. 1992. Biological control against parthenium weed in Australia. *Crop Protection* 11: 400–407.

Mersie W. and Singh M. 1988. Effects of phenolic acids and ragweed parthenium (*Parthenium hysterophorus*) extracts on tomato (*Lycopersicon esculentum*) growth, nutrient and chlorophyll content. *Weed Science* 36: 278–281.

Mew D., Balza F., Towers G.H.N. and Levy I.G. 1982. Antitumour effects of sesquiterpene lactone – parthenin. *Planta Medica* 45: 23–27.

Mishra K.K. 1991. *Parthenium hysterophorus* Linn.: a new record for Nepal. *Journal of Bombay Natural History Society* 88: 466–467.

Narasimhan T.R., Ananth M., Narayana Swamy M., Rajendra Babu M., Mangala A. and Subba Rao P.V. 1977. Toxicity of *Parthenium hysterophorus* L. *Current Science* 46: 15–16.

Nath R. 1988. *Parthenium hysterophorus* L.: a general account. *Agriculture Reviews* 9: 171–179

Navie S.C., Mc. Fadyen R.E., Panetta F.D. and Adkins S.W. 1996. The biology of Australian weeds: *Parthenium hysterophorus* L. *Plant Protection Quarterly* 11: 76–88.

Ovies J. and Larrinaga L. 1988. Transmission de *Xanthomonas campestris* pv. *Phaseoli* mediante un hospedentesilvestre. *Ciencias y Tecnicaen la Agricultura* 11: 23–30 (in Spanish).

Pandey D.K. 1994. Inhibition of salvinia (*Salvinia molesta* Mitchell.) by parthenium (*Parthenium hysterophorus* L.): relative effects of flower, leaf, stems and root residue on salvinia and paddy. *Journal of Chemical Ecology* 20(12): 3123–3131.

Pandey D.K. 1996. Phytotoxicity of sesquiterpene lactone, parthenin in aquatic weeds. *Journal of Chemical Ecology* 22: 151–160.

Pandey D.K. 1997. Inhibition of najas (*Najas germinea* Del.) by parthenium (*Parthenium hysterophorus* L.). *Allelopathy Journal* 4(1): 121–126.

Pandey D.K., Kauraw L.P. and Bhan V.M. 1993. Inhibitory effect of parthenium (*Parthenium hysterophorus* L.) residues on growth of water hyacinth (*Eichornia crassipes* Mart.Solms.): relative effects of flower, leaf, stem, and root residue. *Journal of Chemical Ecology* 19(11): 2663–2670.

Pandey H.N. and Dubey S.K. 1988. Achene germination of *Parthenium hysterophorus* L.: effects of light, temperature, provenanace and achene size. *Weed Research* 28: 185–190.

Patil T.M. and Hedge B.A. 1988. Isolation and purification of sesquiterpene lactone from the leaves of *Parthenium hysterophorus* L.: its allelopathic and cytotoxic effects. *Current Science* 57: 1178–1181.

Paudel V.R. and Gupta V.N.P. 2008. Effect of some essential oils on seed germination and seedling length of *Parthenium hysterophorus* L. *Ecoprint* 15: 69–73.

Paudel V.R, Gupta V.N.P. and Agarwal V.P. 2009. Effect of diffusates of *Parthenium hysterophorus* L. on seed germination of *Raphanus sativus* L. *Scientific World* 5: 29–32.

Picman J. and Picman A.K. 1984. Autotoxicity in *Parthenium hysterophorus* and its possible role in control of germination. *Biochemical Systematics and Ecology* 12 (3): 287–292.

Prati D. and Bossdorf O. 2004. Allelopathic inhibition of germination by *Allaria petiolata* (Brassicaceae). *American Journal of Botany* 91: 285–288.

QNRM 2004. *Facts, Pest Series:* Parthenium *weed (*P. hysterophorus*)*. The state of Queensland, Department of Natural Resources and Mines, Queensland, Australia.

Rajan L. 1973. Growth inhibitors from *Parthenium hysterophorus* Linn. *Current Science* 42: 729–730.

Ramesh C., Ravinath N., Das B., Pravakar A., Bharatam J., Ravikumar K., Kashinatham A. and McMorris T.C. 2003. Pseudoguaianolides from flowers

of *Parthenium hysterophorus* L. *Phytochemistry* 64: 841–844.

Rice E.L. 1984. *Allelopathy*. Second edition. Academic Press, Florida, USA.

Ridenour W.M. and Callway R.M. 2001. The relative importance of allelopathy in interference: the effects of an invasive weed on a native bunchgrass, *Oecologica* 126: 444–450.

Sastry K.S. 1984. Strains of tomato leaf curl virus and its perpetuation under field conditions. *Journal of Turkish Phytopathology* 13: 87–90.

Savangikar V.A. and Joshi R.N. 1978. Edible protein from *Parthenium hysterophorus* L. *Experimental Agriculture* 14: 93–94.

Sharma G.L. and Bhutani K.K. 1988. Plant based antiamoebic drugs. Part II. Amoebicidal activity of parthenin isolated from *Parthenium hysterophorus*. *Planta Medica* 54: 20–22.

Sing H.P., Batish D.R., Pandher J.K. and Kohli R.K. 2003. Assessment of allelopathic properties of *Parthenium hysterophorus* residues. *Agriculture, Ecosystem and Environment* 95: 537–541.

Sing H.P., Batish D.R., Pandher J.K. and Kohli R.K. 2005. Phytotoxic effects of *Parthenium hysterophorus* residues on three *Brassica* species. *Weed Biology and Management* 5: 105–109.

Sing H.P., Batish D.R., Saxena D.B., Kohli R.K. and Arrora V. 2002. Effect of parthenin – a sesquiterpene lactone from *Parthenium hysterophorus*, on early growth and physiology of *Ageratum conizoides*. *Journal of Chemical Ecology* 28: 2169–2179.

Singh H.P., Batish D.R., Setia N. and Kohli R.K. 2005. Herbicidal activity of volatile oil from *Eucalyptus citriodora* against *P. hysterophorus*. *Annals of Applied Biology* 146: 89–94.

Singh S.P. and Sangeeta 1991. Allelopathic potential of *Parthenium hysterophorus* L. *Journal of Agronomy and Crop Science* 167: 201–206.

Srivastava J.N., Shukla J.P. and Srivastava R.C. 1985. Effect of *Parthenium hysterophorus* L. extract on seed germination and seedling growth of barley, pea and wheat. *Acta Botanica Indica* 13: 194–197.

Swaminathan C., Rai R.S. and Suresh K.K. 1990. Allelopathic effects of *Parthenium hysterophorus* on germination and growth of a few multi-purpose trees and arable crops. *International Tree Crops Journal* 6: 143–150.

Tamado T. and Milberg P. 2000. Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of *Parthenium hysterophorus*. *Weed Research* 40: 507–521.

Tamado T., Schutz W. and Milberg P. 2002. Germination ecology of the weed *Parthenium hysterophorus* L. in eastern Ethiopia. *Annals of Applied Biology* 140: 263–270.

Tanner M.S. and Mattocks A.R. 1987. Hypothesis: plant and fungal biocides, copper and Indian childhood lever disease. *Annals of Tropical Paediatrics* 7: 264–269.

Tefera T. 2002. Allelopathic effects of *Parthenium hysterophorus* L. extracts on seed germination and seedling growth of *Eragrostis tef*. *Journal of Agronomy and Crop Science* 188: 306–310.

Tiwari S., Adhikari B., Siwakoti M. and Subedi K. 2005. *An Inventory and Assessment of Invasive Alien Plant Species of Nepal*. IUCN Nepal, Kathmandu, Nepal.

Valliappan K. and Towers G.H.N. 1989. Allelopathic effect of root exudates from the obnoxious weed *Parthenium hysterophorus*. *Indain Journal of Weed Science* 20: 18–22.

Venkataiah B., Ramesh C., Ravindranath N. and Das B. 2003. Charminarone, aseco-pseudoguaianolide from *Parthenium hysterophorus*. *Phytochemistry* 63: 383–386.

Williams J.D. and Grooves R.H. 1980. The influence of temperature and photoperiod on growth and development of *Parthenium hysterophorus* L. *Weed Research* 20: 47–52.