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# Management of perennial weeds under non-cropland hill ecosystems

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**ABSTRACT**

*Lantana camara* L.var. *aculeata, Parthenium hysterophorus* (L.), *Chromolaena adenophorum* Spreng., *Imperata cylindrica* (L.) Beauv,*Urtica dioca* (L.) and *Ageratum houstonianum* (Mill.) are the major obnoxious perennial weeds of non-cropland hill ecosystems. These weeds are difficult to control and have spread like a wild fire in almost all the state because of the favourable climatic conditions, ability to propagate by seeds, stems and roots, faster dissemination by wind, water, birds, animals, machinery *etc*. and ability to adapt adverse conditions of hills. These weeds have become more problematic in hilly regions due to availability of more uncultivated land. These weeds are responsible to suppress useful vegetation in pasture and grasslands, orchards, forests, tea gardens, field bunds and other cropped and non-cropped lands by their competitive and allelopathic effects. These are responsible to threat plant biodiversity, shrinkage of grazing land, economic losses to the forest wealth, reduction in productivity of grasslands up to 90%. The toxins present in these weeds are proving hazardous to the health of animals and human beings. Preventive, mechanical, chemical, biological, utilization and integrated methods to manage these obnoxious perennial weeds have been discussed in this paper. These weeds should be cut at frequent intervals before flowering to exhaust food reserves in their vegetative propagules, check production of seeds and their dissemination. The cut biomass should be utilized to prepare compost, as mulch, biogas production, making furniture, as fuel wood and other industrial uses as per the property of weed species. A three phased integrated technology to manage *Lantana camara* under different hill ecosystems has been developed and demonstrated in large areas. In waste lands and forestland ecosystems, biological agents like *Zygogramma bicolorata*, *Cassia tora* or *Cassia sericea* are effective to manage Parthenium, hence should be introduced to check the rampant growth of this weed. In pasture and grasslands, herbicides should only be used in integration with plantation of fast growing forage species, recommended fertilizer, and harvesting or grazing schedules. These integrated technologies to manage *Parthenium*, *Lantana* and *Ageratum* have been demonstrated on large scale in hilly regions. However, for effective results, these technologies need to be adopted on campaign basis with the active participation of public, Government, scientists and policy makers.

**Key words**: *Ageratum*, Management, Hilly regions, *Lantana*, Non-cropped weeds, *Parthenium*, Perennial weeds

Hilly regions are gifted with plenty of land that can not be put under frequent cultivation. Such lands are under orchards, pastures, grasslands, forests and wasteland ecosystems. Since most of these lands do not receive frequent cultivation and intensive care of the owners, the obnoxious perennial weeds like *Lantana camara, Ageratum houstonianum, Parthenium hysterophorus, Chromolaena adenophorum* and *Urtica dioica* have invaded most of these areas. They are regarded as the worst weeds because of their invasiveness, potential for spread and economic and environmental impacts. Most of these weeds forms dense, impenetrable thickets and take over the native bush land and pastures. They reduce the productivity of pastures, orchards and forestry plantations by their competition for resources and allelopathic effects. The low productivity of these non-cropped ecosystems lead to scarcity of food, fuel wood, fodder, fruits, monkey menace and migration of men to towns and cities in search of jobs after leaving the land fallow. However, the majority of people depend upon their subsistence needs on such uncultivated yet degraded lands. Productivity of such lands can be restored by managing these obnoxious perennial weeds with the available technologies. In this paper, efforts have been made to discuss the biology of important obnoxious perennial weeds of hills, their ecological impacts and management techniques. Some of the major obnoxious weeds of hilly regions are given (Table 1).

These obnoxious weeds have immense capacity of propagation by seeds, stems and roots, high rate of dispersal and adaptation to adverse conditions. These weeds compete with the associated vegetation for nu-

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**Table 1. Major obnoxious perennial weeds of non -cropland hill ecosystems**

| Scientific name | English / local / vernacular names |
|---|---|
| *Lantana camara* L. | Wild sage, Panchfuli, Phulbehri, Chudel buti, Lal phulnu |
| *Ageratum houstonianum* (Mill.) | Bill goat weed, Neela Phulnu, Pudini, Ujaru, Ukhal buti, Shadian |
| *Parthenium hysterophorus* L. | Congress grass, Gajar ghass, Chatak chandni |
| *Imperata cylindrica* (L.) Beauv. | Thatch grass, Chiz, Seerua, spear grass, alang alang, cogongrass |
| *Urtica dioica* (L.) | Stinging nettle, Bitchu booti, Ahn, Common nettle |
| *Chromolaena adenophorum* Spreng. | Crofton weed, Kali basuti, Siam weed, Bitter bush, Charismas weed |

trients, moisture, and light and also suppress the native vegetation by allelopathic effects. They have invaded all such land masses that are not under cultivation or are poorly managed. Hilly regions have more such lands which are under forests, pastures and grasslands, orchards, tea gardens and uncultivable waste lands. Consequently these weeds have led to shrinkage of grazing area for animals, reduction in productivity of grasslands by 90 per cent, threat to plant biodiversity, reduced growth of newly planted trees in man made forests and interference in succession of natural forests, act as hiding place for wild animals and threat to ecology of the region. These weeds also cause toxic effects on animals and are threat to human health and environment.

Ecological implications of obnoxious perennial weeds in hill ecosystem are:

- The pasture and grazing lands in the hills are most affected due to infestation of these weeds. For example, in Himachal Pradesh, pasture and grasslands which constitute about 40% (94.2 million hectares) of the total geographical area provide fodder and grazing ground for the entire livestock population of the state. Taking an average figure of 25% invasion, the invaded area with these weeds comes around 23.55 million hectares. Although, these weeds cause about 90% reduction in productivity of grasses but even if an average of 50% is taken, the total loss of production is estimated to be more than 17.62 million tones, valued at approximately more than ` 90 billion per annum. Besides this ,the robbing of nutrients by these weeds make the land less fertile and further regeneration of grasses is also checked by their allelopathic and interference.
- Though these weeds are not palatable to the livestock due to their aroma, disagreeable taste and presence of trichomes, yet the accidental or willful intake for want of green fodder cause severe syndrome leading to death of cattle grazing in infested areas due to presence of toxic alkaloids.
- These weeds cause allergies like giddiness, loss of hairs, dermatitis, asthma, aczema, vomiting, headache, eruptions on the exposed body parts like eye lids *etc.* and even death due to contact with them or even with their presence in the nearby environment. Consequently, farmers hesitate to uproot these weeds by manual methods and are leaving the land fallow which is further create favorable conditions for their growth and spread.
- Due to fodder scarcity caused due to invasion by these weeds, farmers are leaving their cattle loose for stray grazing which cause damage to the cultivated crops.
- The monkey menace, one of the major problem in the hilly areas is also attributed to impenetrable thickets formed by these weeds and their allelopathic effects has extincted most of the wild fruit plants in the natural forests. In the absence of wild fruit plants, monkeys have shifted to domesticated areas causing lot of damage to the cultivated crops and human dwellings, compelling the farmers to leave their land fallow.
- The fast growth and spread of these weeds prevent establishment of native trees and shrubs thus posing serious threat to the plant biodiversity in natural and manmade forests.
- Most of these weeds like *Lantana* and *Imperata* increase the risk of fires in plantations and forests as they readily burn, even when still green, destroying other vegetation and microfauna while they regenerate very rapidly, thereby displace other plant species
- Increased danger of wild animals to the inhabitants and their livestock.
- Environmental pollution due to pollen grains and volatile compounds released into the environment.
- Make the land barren by exploiting nutrients and moisture from the soil.
- Disrupt insect-plant associations necessary for seed dispersal of native plants.
- Disrupt native plant-pollinator relationships.
- Reduce and eliminate host plants for native insects and other wildlife.

- Hybridize with native plant species, altering their genetic makeup.
- Serve as host reservoirs for plant pathogens and other organisms that can infect and damage desirable native and ornamental plants.
- Replace nutritious native plant foods with lower quality sources.

**Biology of problematic weeds of hill regions**

*Lantana camara* (Linn.) belonging to family Verbanaceae is a woody scrub plant having 150 varieties with different flower colours and heights. Out of these, three varieties namely *aculeata*, *mista bailey* and *nivea bailey* have been reported from India (Gujral and Vasudeva 1983). Among these, *Lantana camara* var. *aculeata* is the most common having yellow or pink flowers changing to orange or scarlet, average plant height 30-120cm, thick pubescent leaves and having good seed production potential. It propagates by seeds, stem and roots and is disseminated by birds through their droppings and feces of moving flocks of sheep and goats who feed on its seeds. The compound lantadene 'A' lantadene 'B' and lancamarone have been reported to be the major toxic compounds present in this plant which cause phytotoxic effect to the animals (Sharma *et al*. 1981). It is also known to directly affect humans (Morton 1962). Its fruits are toxic to the children (Wolf and Solomons 1964). It is one of the ten most toxic weeds in the world (Holm and Herberger 1969). *Lantana camara* is reported to be a native of tropical America (Guana, cuba) and West indies. It has been found to be present in 50 countries but is the principal weed in twelve countries (Holm *et al*.1977) spreading over Oceania, Asia, Africa, South America and North America. It was introduced in India during 1809 as an ornamental plant (Gupta and Pawar 1984) but has now spread to almost all the states but its spread has been fast and abundance more in regions where unculturable wastelands are relatively more. The low and mid hills of Himachal Pradesh, Uttarakhand, Jammu & Kashmir and Eastern regions have been found to be very favorable for its luxuriant growth. It is spreading like a wild fire each year and is causing damage to the ecology thus increasing economic losses in term of forest wealth, livestock and reduced productivity of pastures and grasslands.

*Ageratum*, a herbaceous plant belonging to the family Asteraceae has two species namely *Ageratum conyzoides* L. and *Ageratum houstonianum* (Mill). Former is an annual weed infesting mainly cultivated upland *Kharif* crops like pulses, oilseeds and vegetable crops. It emerges in July and completes its life-cycle by October. Flowers are white to blue in colour and propagation is mainly by seed. The latter species is perennial invading uncultivated lands like pastures and grassland, orchards, tea gardens, forests, field bunds, wastelands and water channels. *Ageratum houstonianum* has violet- blue flowers and propagate through seeds, stem and roots. It has potential to produce up to 94,772 seed per plant having pappus structure at one end of the seed which help it to disseminate by wind, water, animals and machinery. Optimum and minimum temperature for germination of its seeds is 30-35 $^{o}$C and 20 $^{o}$C, respectively. The seeds remain dormant for 3 months (Angiras and Kumar 1995). Emergence occurs during June and October. The period of maximum growth is March-April. Alkaloids precocene-I & II, present in this weed cause giddiness, headache, skin and eye irritation to human beings and hazardous to animals when consumed with fodder. *Ageratum* is a native of tropical America and was introduced as an ornamental plant in India. Still, it is being grown as an ornamental plant in Gujarat. Because of favorable conditions for its germination, growth, development and seed production in hills and its faster rate of dissemination by wind, this weed has spread like a wild fire first in hilly regions and gradually to the plains. Although, it has spread to almost all the states of India but at present it is a serious problem in Himachal Pradesh (all districts except Lahaul and Spiti and Kinnaur), Punjab, Haryana, Assam, Uttarakhand and Uttar Pradesh.

*Parthenium hysterophorus*, a native of West indies and tropical North and South America, is an herbaceous plant belonging to family Asteraceae. It was introduced in India accidentally along with imported wheat from USA under PL-480 programme in 1955. Since then, it has invaded 35 million hactare land in India (Sushilkumar and Varshney 2010). It is a photothermo insensitive plant growing throughout the year and has invaded non cultivated and cultivated areas. The genus *Parthenium* has 20 species growing to a height of 1.0 -1.5 m. But *P. hysterphorus* is the most dominant as a weed. Morphologically characterized by angular longitudinally grooved, profusely branched hairy stem, irregularly dissected carrot like or *Chrysanthemum* like leaves with white flower heads. It propagates by seeds and crown buds. It gets disseminated by wind, water, machinery and animals especially sheep and goat. It may produces up to 25000 seeds from a single plant which are non-dormant and germinate at 25-30 $^{o}$C. The plant normally completes its life-cycle within four months. Periodicity, however depends upon frequency and distribution of rains during the year. Accordingly, the plant completes 2-3 generations in a year. Under adverse conditions, plants remain dormant in vegetative phase and propagate through roots and stem. This characteristic helps it to

persist over longer periods and makes difficult to control. Phyto-sociologically, it is rapid colonizer and outgrows other vegetation in its vicinity within two growing seasons. The average height of plants of *Parthenium* in hilly areas was recorded upto 2.09 m and its root system deep upto 17.32 cm below the ground level. It produced enormous number of seeds which help in its invasion in to various habitats. It was estimated that single plant of *Parthenium* produce more than 7397 seeds during one season. The seeds were lighter in weight and were 2.31 mm in length and 1.03 mm in width. In the Nort-West Himalaya, *P. hysterophorus* completed its two life cycles in one year, that is, from March to June and from July to November (Dogra *et al*. 2009)

*Imperata cylidrica*, a native of tropical America are rhizomatous, $C_4$ perennial grass weed belonging to the family *Poaceae*. It propagates by rhizomes and seeds but disseminate by wind and machinery. It flowers in April-May and September-October months. It colonizes rapidly in abandoned farm lands, orchards, tea gardens, field bunds, roadsides, pasture and grasslands suppressing the growth of other vegetation. Weed develops a thick mat of slender branched yellow-brown rhizomes just below the soil surface which produce slender leaves of 25-30 cm long. It produces feathery inflorescence among the leaves. It is fast disseminated even by light wind and seeds require moist conditions for germination. One plant can produce uptp 3000 seeds, which have little, or no dormancy period and may remain viable for over a year (Santiago 1965). Soon after germination, the plant starts to produce rhizomes and form dense stand in few years. Its spread is favoured by regular burning or slashing which removes competitors and helps to grow rapidly from the protected rhizomes. Allelopathy also helps them to compete with other species and its dominace in large area. The aggressive and invasive nature of *I. cylindrica* is attributed to its rhizomes. These are normally concentrated in the upper 15-20 cm of soil where they can remain dormant but viable for a long time (Ivens 1980). Rhizomes have a high regenerative ability because of the numerous buds that readily sprout into new shoots after fragmentation by tillage or any other form of disturbance. Rhizomes are resistant to fire because of deep soil burial. Deep burial also makes *I. cylindrica* very resistant to most control strategies (Holm *et al.* 1977, Ivens 1980). The ability of rhizome fragments to regenerate decreases with a reduction in length of rhizome segment. Longer rhizomes have better chances of sprouting because they have more carbohydrate reserves than short fragments (Ivens 1975).

*Imperata cylindrica* can grow on soils with a wide range of nutrients, moisture and pH (Santoso *et al.* 1997). Although, sometimes reported to be a weed of poor soils, *I. cylindrica* probably dominates these areas because of lack of competition from other plant species that cannot survive on marginal land (Santoso *et al.* 1997). It is a poor competitor and is easily suppressed by other species on fertile soils (Eussen and Wirjahardja 1973). It does not tolerate shaded environments because it assimilates carbon via the $C_4$ photosynthetic pathway (Paul and Elmore 1984). It is a strong competitor for growth factors such as water, nutrients, and light and sprouts and grows more rapidly than crops ($C_3$ plants).

*Chromolaena*, synonymus to *Eupatorium* and *Ageratina*, considered to be the native of Mexico and Jamaica belongs to the family Compositae have around 500 species all over the world. But in India *Chromolaena adenophorum*, *Chromolaena odora* and *Chromolaena riparium* are the most dominating species in hilly regions of North-East, North-West and Southern regions of India. Among these, *C. adenophorum* dominates in Himachal Pradesh. In India, it was introduced as an ornamental plant in 1924 and thereafter it naturalized Nagaland and other hilly states of the country. It flourishes in the areas located between 550 to 2000 m above mean sea level having year round rainfall and has overcome the native vegetation. There are reports that its faster growth and allelopathic effects even suppress the *Lantana camara* during rainy season. In hilly areas, it grows luxuriantly about 0.8-1.5 m tall on road sides, abandoned fields, sides of irrigation channels, pasture and grasslands, water channels, thin pine forests and tea gardens. It produces more than 3000 seeds per plant having more than 75 per cent viability. In Himachal Pradesh, this weed germinates in April–May and the plant grows vegetatively up to November-December with fast growth during June–September. Flowering starts in the last week of January and full blooming is observed in first week of April. The flowers are small and white in colour. The weed propagates through seeds as well as vegetative parts and is disseminated fast by wind, water and animals (Singh *et al.* 1996).

*Urtica dioica* (stinging nettle), a native of Europe and North America is a herbaceous perennial weed belonging to the family Urticaceae, 1 to 2 m tall in the summer and dying down to the ground in winter. It has widely spreading rhizomes and stolons, which are bright yellow as are the roots. The soft green leaves are 3 to 15 cm long and are borne oppositely on an erect wiry green stem. The leaves have a strongly serrated margin, a cordate base and an acuminate tip with

a terminal leaf tooth longer than adjacent laterals. It bears small greenish or brownish numerous flowers in dense axillary inflorescences. American stinging nettle and hoary nettle are predominantly monoecious whereas European stinging nettle is typically dioecious. The fruit is an achene.

Stinging nettle may reproduces vegetatively and by seeds. It produces abundant seeds. Plants growing in the shade produce approximately 500 to 5,000 seeds per shoot and plants growing in full sunlight produce 10,000 to 20,000 seeds per shoot. Seeds are not dormant and can germinate 5 to 10 days after maturity (Basset *et al*. 1977). It is found mostly in soils rich in phosphate and Nitrogen. The leaves and stems are very hairy and also bear many stinging hairs (trichomes), whose tips when touched, transforming the hair into a needle that will inject painful chemicals. As a perennial weed, common nettle is troublesome around the margins of arable fields, pasture and grasslands, gardens and often encroaching into the fields under mid and high hills.

**Management strategies**

Perennial weeds are usually more difficult to manage than annuals because of their capacity to reproduce by vegetative means as well as seeds. In pastures and grasslands, proper management to establish and maintain desirable forage species is critical to prevent or retard the successful establishment of perennial weeds. The effective management of perennial weeds require integration of prevention, mechanical, utilization of cut biomass, chemical methods and utilization of the land as per its capability with improved practices. In addition, the control of shoot growth must be continued throughout the year. Different techniques which can help in managing these weeds are discussed hereunder.

**Preventive approaches**

The spread of these weeds can be checked by many ways described by (Angiras 2000). This can be achieved by:

- Creating awareness among public through press and media, field days and mass rallies in schools, colleges and universities about the harmful effects of these weeds so that people may remove the new plants entering in their areas before flowering.
- Educating the farmers not to leave the land fallow and to avoid use of feed and fodder from areas invaded by these obnoxious weeds.
- Creating competitive environment by managing the pasture and grasslands by planting improved grass species and favouring their growth and development with recommended fertilizer application, rotational grazing and cutting management techniques *etc*.
- Avoid over grazing beyond carrying capacity of the pasture lands.
- Avoid grazing of sheep and goats in *areas* invaded by these weeds.
- Monitor tourist places for presence new weed plants and kill them before flowering.
- Adopt phytosanitary measures by cleaning machinery, vehicles and livestock coming from weeds invaded areas.
- Manage these weeds on road sides through road maintenance staff of the Public Works Department as the first entry of these weeds in new areas occur along the roadsides and thereafter invade adjoining non cropped lands.

**Mechanical methods**

It involves physical methods of removing the weeds by manual or through machinery before flowering by:

- Slashing, burning and uprooting of obnoxious weeds immediately after rains.
- Frequent cutting before flowering to check seed formation and to exhaust, the food material of vegetative organ.

*Lantana camara* can be managed by following principal of destroying its food reserves, stoppage of food supply for their survival and and creating competition by growing useful vegetation. It involves cutting, pulling of the stumps during rainy season, planting of competitive plants or grasses and frequent uprooting of re-growth (Katoch 1988). This method is highly labour intensive and can not be applied in rocky areas and on steep slopes due to danger of soil erosion.

Six cuttings per year at 45 days interval from March or four cuttings at an interval of 45 days from July was also found to be effective to completely exhaust the food material in the roots to kill the plant completely without any regeneration (Singh and Angiras 2011). *Ageratum* and *Parthenium* plants should be cut or uprooted before flowering at frequent intervals. Put the cut biomass in compost pits with alternate layers of dung or prepare compost or vermicompost. Since the roots of *Chromolaena* are shallow, it can easily be uprooted during the rainy season before flowering. The uprooted biomass can be used for composting (Singh and Angiras 2008) or as mulch in the field. Three cuttings at 45 days interval from May or two cuttings at 45 days interval from

August exhausted the food material of the roots completely and did not allow it to regenerate thereafter (Singh and Angiras 2010). Frequent ploughing of land during hot weather expose the rhizomes of *Imperata cylindrical* and *Urtica dioca*to the drying action of the sun rays.

**Biological methods**

Both the classical biological control and use of allelopathic and competitive plants have been found effective to manage these weeds in areas where seasonal fluctuations in temperature and humidity are less. The effective bioagents and botanicals are given (Table 2)

**Table 2. Bioagents for biological control**

| Weed | Biological agents |
|---|---|
| *Lantana camara* | Lace bug - *Teleonemia scruplosa* (Sushilkumar 1993, 2001)<br>Flower feeder - *Asphondylia lantanae*<br>Fruit borer - *Homona micaceana*<br>Stem and root borer - *Plagiohamus spinipennis, Epinotia lantanae* |
| *Ageratum houstonianum* | *Cassia tora* (Angiras 1998) |
| *Parthenium hysterophorus* | Mexican beetle - *Zygogramma bicolorata* (Sushilkumar 2006, 2009)<br>Allelopathic and Competitive plant *Cassia sericea* (Joshi 1989), *Cassia tora (*Angiras and Saini 1997, Sushilkumar and Bhan 1997, Sushilkumar and Varsheny 2007, Sushilkumar 2009)<br>Gall midge - *Orsioliella javanica* |
| *Chromolaena adenophorum* | Gall fly (*Procecidochares utilis*), Fungus - *Cercospora eupatrii* (Singh 1989, Sushilkumar 1993) |

**Integrated methods**

These obnoxious weeds can effectively be managed by integrated approach of chemical, mechanical and biological methods.

***Lantana camara:*** Three phased integrated technology has been developed at CSKHPKV by Angiras *et al*. (1988) and demonstrated in large areas (Table 3) in farmers field as follows:

- Cut the *Lantana* bushes in August-September at 5-7 cm above ground and utilize the cut biomass for making furniture, vermicompost, charcoal brickets, agarbaties, mulch and fuel wood *etc*.
- Apply glyphosate 0.41% or 0.31% + surfactant 0.1% in September-October on 30-45 cm regenerated foliage.
- Utilize the land as per its capability to avoid emergence of other weeds by planting fast growing grasses (*Setaria, NB-37, Guinea*), fodder trees and other useful vegetation.
- Uproot or give spot treatment on plants (1-2%) emerging from already fallen seeds.

This technology has also been tested by other scientists in other states like Jammu & Kashmir (Sharma *et al.* 2012).

**Table 3. Rehabilitation of *Lantana camara* invaded lands**

| Sites/District | Land use system | Approximate area (ha) |
|---|---|---|
| Saliana, Kangra | Pasture and grassland | 10 |
| Bandla, Kangra | Pasture and grassland | 15 |
| Ghaneta, Kangra | Forest and pasture land | 1 |
| Haroli, Una | Pasture and grassland | 4 |

***Ageratum houstonianum:*** This may be controlled as follows:

- Apply atrazine 1.5 kg/ha on emerging plants at their 2-3 leaf stage in May-June and or September -October by spray or broadcast application after mixing with 150 kg sand in grassland or pastures (Angiras 1998) or
- Apply glyphosate 1.5 kg/ha in 800 L water in May-June and September- October on old *Ageratum* plants before flowering (Angiras and Kumar 1995).
- Plant the improved grasses like *NB-37, Setaria,* Guinea grass *etc*. as per agroclimatic conditions.
- Apply atrazine 1.5 kg/ha or 2,4-D (Na) 1.5 kg/ ha, if new plants emerge from seed already fallen in the soil (Angiras and Kumar 1995).
- Broadcast seeds of *Cassia tora* so that 35-40 plants/$m^2$ are maintained in wastelands (Angiras 1998).
- Cut or slash or spray paraquat 0.6 kg/ha at frequent interval before flowering on campaign basis so that further spread is checked.

In Hamirpur and Kangra district of Himachal Pradesh, at five large sites, *Ageratum* invaded area was rehabiliated (Table 4)

**Table 4. Rehabilitation of *Ageratum* invaded lands**

| Site | District | Land use system | Area (ha) |
|---|---|---|---|
| Dhadamb | Kangra | Wasteland, pasture and grassland, orchard & cultivated land | 3 |
| Garh | Kangra | -do- | 3 |
| Bharmoti | Hamirpur | Wasteland, pastureland & orchard | 3 |
| Jajoli | Hamirpur | -do- | 3 |
| Bara | Hamirpur | Whole village | |

***Parthenium hysterophorus*:** The following integrated technologies for different ecosystems have been developed and demonstrated on large scale (Sushilkumar and Varsheny 2007, Angiras and Kumar 2010):

- Wasteland ecosystem: Spray of glyphosate 0.5% before flowering + release of 350 adults of *Zygogramma bicolorata* during June-July + broadcast of seeds of *Cassia tora* by mixing with dung and soil.
- Grassland ecosystems: Spray of 2,4-D ethyl ester 0.2% / metribuzin 0.25%/ atrzine at 2-3 leaf stage + manual removal of old plants .
- Fertilize with 30 kg N/ha to stimulate and restore the growth of indigenous grasses to suppress the growth of *Parthenium*.
- Introduction of improved grasses like *NB-37, Setaria*.
- Forest land ecosystem: Introduction of *Zygogramma bicolorata* and broadcast of *Cassia tora*
- Roadsides: Mechanical removal by Public Works Department; spray of glyphosate 0.5 % + broadcast of *Cassia tora* seeds by mixing with dung and soil before the onset of monsoons + release of *Zygogramma bicolorata*.

In Kangra district, this technology was successfully demonstrated at Bairghatta area in abut 50 hactare land.

***Imperata cylindrica:*** This weed may be managed by following approach:

- Hot weather cultivation during May-June by deep ploughing
- Spray glyphosate 1.0 kg/ha or glyphosate 0.75 kg/ha + surfactant 0.5% in June or dalapon 4.5 kg/ha in February or paraquat 0.6 kg/ha or cheeling (scrapping of existing weeds with spade) followed by spray of oxyfluorfen 0.25 kg/ha (Angiras *et al*. 1990).

***Urtica dioca:*** This may be managed by following method:

- Cut the well grown stinging nettle plants close to the ground during dry periods and burn or compost the cut biomass. This will help to dry the surface roots in the sun and dry wind.
- Cut the overgrown plants and leave them to dry in the grazing areas for drying. The livestock eat the wilted plants and also damage the rootstocks by their trampling action
- After cutting, uproot the rootstocks as thoroughly as possible or give frequent surface cultivation or hoeing to exhaust the rootstocks eventually
- Spray glyphosate 1.5 kg /ha in waste lands or 2,4-D ethyl ester 0.75 kg/ha in pasture and grasslands on the newly generated seedlings
- Grow competitive grasses.

**Utilization**

Some studies have also been conducted on their utilization to check their further spread. Except some, most of the uses have not been exploited on commercial scale.

- Use as a fuel wood, biogas production, mulch and raw material for paper pulps, agarvatis, dhoop, baskets and furniture making, *etc*.
- These are rich source of plant nutrients after composting (Singh and Angiras 2011) and can add 30-40 kg N/ha.
- *Ageratum* has been used to protect the potato from attack of potato tuber moth.
- *Chromolaena adenophorum* has been reported to contain essential oils like 1-phellandrene, torreyol, anthemol and borryl (Katoch *et al*.2013). Therefore can be exploited as a valuable source for pharmaceutical industry.
- Extracts of these weeds have insecticidal, bactericidal, herbicidal and amoebicidal properties.
- These weeds may be utilized to checks soil erosion.
- Stinging nettle has been used as a food plant when young and tender. Plant is a rich source of protein, iron, calcium and magnesium and is considered to have the medicinal value. Fibres from the stem were used to make linen and ropes

**Future research and management strategies**

- Assessment of land area invaded by these weeds and losses by these weeds on environment, animal and human health and bio diversity required to be made with sophisticated techniques at national level.
- Antidotes against *Lantana, Parthenium* and *Ageratum* poisoning in animals and human beings are required to be investigated.
- Identification of allelochemicals and insecticidal factors are required to be investigated for development of bio herbicides and bio insecticides of the future.
- Biological agents to control these weeds are required to be investigated.
- Integrated technology to manage these weeds in respective areas on campaign basis with the involvement of Government agencies, scientists and people participation required to be developed.
- Need to screen competitive useful plant species to replace the obnoxious weeds in natural ecosystem.

- Mass education through extension activities regarding their hazardous effects need to be imparted.
- Need to adopt strict quarantine measures and mechanisms to monitor the introduction of new weed species at regular intervals and their management
- These weeds can be managed successfully by giving priority to manage them in Hills as they continue to act as a source of seed for the plains
- Need to create national level obnoxious weed management body to monitor and plan strategies to use the developed technologies on campaign basis at national level.

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