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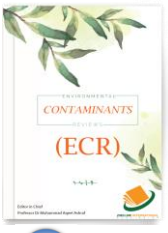

RESEARCH ARTICLE

BIOLOGY AND CONTROL METHODS OF THE ALIEN INVASIVE WEED MIKANIA MICRANTHA: A REVIEW

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ABSTRACT

Invasion of alien weed species is one of the most serious global problems. Different bioclimatic conditions of Nepal favor the introduction of different invasive alien weeds. *Mikania micrantha* (L.) Kunth is one of the well-established invasive alien weeds in the tropical and sub-tropical parts of eastern and central Nepal. *M. micrantha* was first reported in 1963 in the eastern part of Nepal and then spreading towards the western part, which is now recorded in over 20 Terai districts of Nepal. Its spread is causing a serious threat to native ecosystem and in the protected areas too, such as the Koshi Tappu Wildlife Reserve and the Chitwan National Park. It invades new areas by seed dispersal and, once established, it spreads locally by ramets produced by penetrating rosette caudices and ramet caudexes. This neotropical vine supplants other plants and reduces biodiversity significantly by swamping vegetation and out competing native plants. Regeneration of other plants in its invaded area is restricted due to its high dispersal ability and adaptability to colonize in new habitat and difficult to control if once established. Several measures have been attempted in controlling this weed, but till date little success has been achieved in Nepal. It is important to identify the control measures which are: socially acceptable; economically viable and spatially suitable. There is consumption of extra human resources and time for clearance of *Mikania* in their cultivated lands and also an extra expenditure is required to avoid the impact of *Mikania* which is affecting livelihood of local people. As *M. micrantha* grows rapidly and conventional control measures are costly and time consuming, biological control is seen as a feasible, environmentally friendly and self-sustaining option to control large stands of *M. micrantha*. Co-evolved rust pathogen, *Puccinia spegazzini* has been reported to be able to control the weed and introduced in countries like India, Taiwan, China, Papua New Guinea and Fiji.

KEYWORDS

Mikania micrantha, invasive, neotropical, biological control, *Puccinia spegazzini*.

1. INTRODUCTION

Mikania micrantha H.B.K. (Asteraceae) is a fast-growing plant capable of climbing over other plants to gain more sunshine. It is also known as plant killer as it spreads appallingly fast, blocking sun light for other plants, and strangles many plants, which wither as a result [1]. Although intolerant of heavy shade and water logging condition, it readily colonizes gaps. It has been reported that its shoot grows about 27mm per day and a single plant may cover 25 sq. meters within few months. It is also reported that the vine releases growth inhibiting substances [2].

Mikania micrantha weed was earlier nominated as among 100 of "world's worst" invader [3] and was later ranked among their top 10 worst weeds by Oceania on March 2002 and 2004 at two regional technical meetings on plant protection and insecurity [4]. In addition, the vine has been listed as one of the three worst weeds of tea in India and Indonesia and of rubber in Sri Lanka and Malaysia. Invasions of *M. micrantha* in Samoa have caused the desertion of coconut plantations, and the weed has been reported to kill large bread fruit trees.

M. micrantha is a serious weed of agriculture, affecting over 20 species, including plantation trees such as species of *Citrus, Theobroma cacao* (cocoa), coffee (species of *Coffea*), *Camellia sinensis* (tea), *Tectona grandis* (teak), *Hevea brasiliensis* (rubber), *Elaeis guineensis* (African oil palm), *Cocos nucifera* (coconut) and *Bambusa vulgaris* (common bamboo) [5]. *M. micrantha* produces allelochemicals which have been shown to inhibit the germination of a number of agricultural seeds. It can also compete with pastures, causing a decrease in livestock production [6].

Similarly, *M. micrantha* is ascertained as one of the six high risks posed invasive alien species in Nepal and later on considered to be the most problematic in terrestrial ecosystem in eastern and central Nepal [7,8]. In Chitwan National Park (CNP), *M. micrantha* was found to be the most serious weed among the eight invasive species in terrestrial ecosystem [9]. High invasion of *Mikania* has occurred in the northern part of core and buffer zone of the CNP [5]. This weed has been creating a serious threat in other protected areas such as the Chitwan National Park Reserve Buffer Zone and the Koshi Tappu Wildlife Reserve Buffer Zone by suppressing the growth of native plants and preventing the regenerations of other plants due to its high dispersal ability and adaptability to colonize in new habitat. The vulnerable greater one-horned rhinoceros is under threat as *M. micrantha* outcompetes plant species on which it browses [10].

Manual control of the vine infested areas has been carried out traditionally by rolling, drying and burning the plants but this proved to be unsustainable [11]. However, *M. micrantha* has been the target of a biological programme for many years. As a result, most reports of natural enemies have been with this in mind. Recent studies have suggested *Puccinia spegazzinii* de Toni (Pucciniaceae) to be the most promising biocontrol agent against this vine as it was observed infecting both old and young leaves and petioles, causing premature senescence [12].

2. METHODOLOGY

This paper aims to give a brief description on the biology, ecology, effects and management methods of the invasive weed: *Mikania micrantha*. Necessary information were gleaned through various literature and reliable information on M. micrantha including the weed problem, weed origin/distribution, biology, field incidence and control measures. Relevant information were arranged systematically. Findings are briefed

in texts with conclusive outline of emerging threats and weed management.

3. RESULTS AND DISCUSSION

3.1 Origin and Invasion history

It is native to Central and South America, with some representatives native to Asia and southern Africa [13]. There are over 200 species in Brazil alone [14]. Within this native range, it is restricted mostly to riparian habitats, typically occurring around the margins of rivers, lakes and marshy terrain and is rarely invasive [15]. In sharp contrast, throughout its exotic Palaeotropical range, *Mikania micrantha* is an extremely serious weed with an exceptionally fast growth rate, 8-9cm/day and it justifiably has earned the common name of mile-a minute weed [16,17]. *Mikania micrantha* was introduced into the Old World, probably on several occasions, some of which have been substantiated. The neotropical vine was first reported in the Old World in Asia in 1884 in the Hong Kong Zoological and Botanical Gardens, and by 1919 it was considered naturalized [18].

It was reported in mainland China (Guangdong Province) in 1910 and is now also present in Yunnan, Hainan, and Jiangxi Provinces and Guangxi Zhuang Autonomous Region, all in southern China [19, 20]. It was reportedly introduced into Taiwan for soil conservation in the 1970s, although noted that the first specimen collected in Taiwan was in 1986 in Pingtung County [21,22]. Studies suggest that *M. micrantha* was present in Calcutta as early as 1918 (presumably in the Botanical Gardens, via Kew Gardens). Also, considerable anecdotal evidence concerning the introduction and use of *M. micrantha* in Assam as an airfield camouflage in World War II are reported [16].

In 1949, propagules was received by the Botanical Garden Bogor from Paraguay and was then introduced as ground cover for rubber plantations in 1956 [23,24]. As mentions a verbal communication that *M. micrantha* was introduced into the Philippines from Acapulco, Mexico, but we have not been able to substantiate this report [25]. At least two biotypes are considered in West Malaysia, one hairy and the other smooth, suggesting separate introductions. *M. micrantha* is different in both the Old and the New World undoubtedly. Scientists of CABI Bioscience have been examining the DNA taxonomy of individuals from diverse localities in the Neotropical and Oriental Regions, and this will be reported at a later time [26].

3.2 Geographic Distribution

The indigenous range of *M. micrantha* ranges from Northern Argentina to Mexico including many nations in the Caribbean [27]. A group researchers suggests that the two major centers of diversity for *M. micrantha* are the eastern foothills of the Andes stretching from Bolivia to Colombia and the highlands of southeastern Brazil [17]. In its introduced range, *M. micrantha* is found between the latitudes of 30° N and 30° S. It is present throughout Asia, from Pakistan to Taiwan, including Nepal, the Philippines, and Indonesia. It is also found on the islands of Mauritius, La Reunion, Christmas, and Sri Lanka in the Indian Ocean [28].
It is as yet absent or unreported in some Pacific islands, notably the Hawaiian Islands and Japan, which may be due to their relatively northern latitude and /or their relative isolation.

3.3 Invasion history in Nepal

Incursions in the different tropical ecosystems of Nepal (forest, cropland, grassland, and wetland) distributed from Mechi to Lumbini zones (Ilam/ Jhapa to Rupandehi districts) has been rapid by the weed since few years. It is not reported west to Rupandehi. *Mikania* is now recorded in 20 eastern and central Terai districts of Nepal including three protected areas such as CNPBZ, Parsa Wildlife Reserve (PWR), and KTWRBZ [29]. Bakhre lahara, Pyangri lahara, Pani lahara, Bahra mase, Banlude jhar, Lahara banmara, Bire lahara, Tite lahara are the popular names of the weed according to varied local Nepali dialects [10]. The weed was first collected in 1963 by a Japanese team from the Jogmai-Ragapani area of Illam district of east Nepal, and scientifically reported in the Flora of Eastern Nepal in 1966. Illam is famous for tea gardening and Assam (north east India) is the main centre for providing tea seeds or saplings to Illam. Thence, it can be supposed that the weed was introduced to Nepal via north east India (Assam) and has been spreading towards west [30]. In the year 2050 BS, *Mikania* originated in the periphery of CNPBZ after the Rapti River flooded the region and spread intensively during the period 2060-66 BS [30]. Further dispersal was possibly because of numerous small seeds blown by air or due to vehicles, livestock and humans. Stem fragments and small seeds may easily be contaminated with agriculture, pasture, forestry and horticulture seeds [7].

3.4 Ecology

In its native range, area of invasion of the mile-a-minute weeds extends up to 3,000 m above sea level [31]. It has been suggested that most of southern Asia and most tropical islands in the Pacific are climatically suitable for *M. micrantha* on the basis of a CLIMEX model based on the native distribution of M. micrantha [32]. *M. micrantha* can be diploid (2n = 2x = 36), aneuploid (2n = 2x = 42), or tetraploid (2n = 2x = 72) in its native range [33]. The vine grows successfully in a wide range of conditions, but grows optimum where soil fertility, light intensity, temperature, , rainfall, organic matter, and air humidity are all high [34].

Mikania grows profusely on leached and nutrient poor sandy loam to clayey soils. W.H.Ye (2001) suggests that *M. micrantha* grows in moist soils, whether acidic or alkaline (pH- 4.15-8.35), and from less fertile to highly fertile soils [35]. It grows best where annual temperature is > 21 degree Celsius, soil moisture> 15% and shows positive response to high potassium levels in soils [36]. It has strong phototaxis, and growth rates tend to increase with increasing light intensity. In heavily shaded areas (<25% light), such as on the forest floor, it grows poorly and is rarely found in undisturbed forests [37]. It can also invade aquatic habitats such as ponds, covering and killing aquatic plants such as *Eichhornia crassipes* [19]. Heavy grazing and browsing promotes the spread of *Mikania micrantha*.

Mikania can smother, penetrate crowns and choke and pull over plants. It thus causes a significant reduction in the growth and productivity of several crops. It successfully competes with trees and other crop plants for soil nutrients, water and sunlight. The weed can reduce light interception by covering the canopy of trees. Damage due to *Mikania* is high in young plantations compared to older ones since the weed can easily smother young trees. The adverse effect of *Mikania* on crops and soil properties is through the production of phenolic and flavanoid compound [38].

3.5 Biology

Mikania micrantha Kunth belongs to Phylum Angiospermae, class Magnoliopsida, order Asterales, family Asteraceae, tribe Eupatorieae, genus *Mikania*. Being the largest genus in the tribe Eupatorieae in the family Asteraceae, it comprises of about 400 species [27]. Mile-a-minute weed is a vigorously-growing, perennial and many-branched vine with a twining, climbing or creeping habit. Stems grows up to 6 m or more long [17].

3.5.1 Distinguishing Features

- ✓ A long-lived vine with slender ribbed stems and oppositely arranged leaves.
- ✓ Its leaves are heart-shaped or somewhat triangular, hairless, and have coarsely toothed margins.
- ✓ Numerous fluffy white flower-heads are borne in branched clusters in the leaf forks or at the tips of the branches.
- ✓ The tiny black seeds (1.5-2 mm long) are topped with numerous whitish colored hairs or bristles (2-4 mm long) [39].

3.5.2 Stems and Leaves

The slender stems are ribbed lengthwise (i.e. longitudinally) and are either glabrous or slightly puberulent. Adventitious roots are produced sometimes at the nodes of stems. Leaves are borne on petioles i.e. 2-8 cm long, are glabrous and have dentate margins [19].These leaves are either heart-shaped (i.e. cordate) or somewhat triangular in shape with a long pointed tip (i.e. acuminate apex) and oppositely arranged (4-13 cm long and 2-9 cm wide) on the stem.

3.5.3 Flowers And Fruit

Many fluffy flower-heads (i.e. capitula) are produced in branched clusters originating in the forks of the leaves or forming at the tips of the branches (i.e. in axillary or terminal corymbs). These capitula are greenish-white or white in colour, disciform and small (3-6mm long). They do not possess any obvious petals and consist of four tiny flowers (i.e. tubular florets), each 3-4 mm long, surrounded by a row of four small green bracts (i.e. involucre) [40]. These bracts (2-4 mm long) are egg-shaped to oblong in outline (i.e. obovate) with pointed tips (i.e. acute apices). Flowering occurs mostly from late autumn through to early spring. Flowers mature 5 days from bud formation, and anthesis requires another 5 days, with seeds maturing in 5 – 7 days [41]. The tiny blackish-brown or black seeds (i.e. achenes) are elongated (i.e. linear-oblong) in shape and five-angled in cross-section. These seeds (1.2-2 mm long and 0.2-0.6 mm wide)

are topped with a ring (i.e. pappus) of numerous (30-38) whitish colored hairs or bristles (2-4 mm long) [31].

3.6 Reproduction And Dispersal

M. micrantha reproduces vegetatively via stem fragments that can readily develop into new plants and also by seeds. The main mode of propagation is vegetative. Fruit setting occurs between September and February, initiated 17 - 21 days after flowering. A single stalk of the vine can produce 20,000 - 40,000 mature seeds in one season. Flowering and fruiting occurs in November- February. Dispersal of the seeds occurs between October and April and the mean number of seeds per mg is 108 ± 12. Wind, animals and water currents are the means of seed dispersal over long distances. The germination percentage of seeds is very low (8-12%) compared to other weedy species. Light, water, soil nutrients and fire affect the germination of seeds [7].

3.7 Physiology

Mikania can produce a large quantity of biomass in a single life span being a C3 plant. It is a heliophilic species, which means, it is adapted to living in full sunlight and greatest biomass is produced under these conditions [42]. Under high light conditions, *M. micrantha* typically produces thicker leaves, accompanied by greater photosynthetic efficiency [18]. The relatively high light utilization of *M. micrantha* compared with that of other species suggests a strong competitive ability and favors its rapid colonization of new areas. Increased photosynthesis has also been shown to be related to increased allelopathic impacts of *M. micrantha* through enhanced allelochemical production. Conversely, under heavy shade conditions of <2,000 lux, growth, photosynthetic efficiency, and photosystem II activity of *M. micrantha* were observed to be very low, thus reinforcing the heliophilic nature of M. micrantha [43]. Chlorophyll and xanthophyll content decrease under low irradiance. Chlorophyll content and maximum photochemical efficiency of photosystem II of *M. micrantha* has been found to decrease under drought and nonphotochemical quenching increases [34].

Some researchers isolated 59 chemical compounds from *M. micrantha* in a comprehensive phytochemical analysis with the major constituents being steroids (44.58%), esters (26.22%), amides (9.45%), heterocyclic compounds (5.34%), and ethers (4.87%) [44]. Bravo Monzon et al. (2014) identified 22 components of volatile oils from *M. micrantha* using various extraction techniques, with the major components being mono- and sesquiterpenes, alcohols, and ketones and their derivatives [45]. These oils showed inhibitory effects against insects, including *Plutella xylostella* L. (Lepidoptera: Plutellidae), *Phyllotreta striolata* Fabricius (Coleoptera: Chrysomelidae), and *Phaedon* brassicae Baly (Coleoptera: Chrysomelidae), and likely confer protection against herbivory [46, 47]. Recent evaluation of aqueous *M. micrantha* leaf extracts on target cancer cell lines and cell growth parameters showed considerable biological activity and potent antitumor activity of extracts, with tumor inhibition rates ranging from 12% to 47% [48,49].

3.8 Ecological Impact

Other researchers suggested that *M. micrantha* conserves large quantities of potassium in its biomass and therefore exerts considerable influence on nutrient cycling in secondary succession after slash- and- burn agriculture. Growth of M. micrantha has a profound effect on soil by increasing numbers of aerobic bacteria [50]. Wong reported that the rate of nitrification was lower under *M. micrantha* than under grasses and legumes [51]. They observed maximum enzymatic activity, influenced by soil pH and organic matter, in *M. micrantha* infested communities, intermediate in ecotones and lowest in the native communities [52]. A group researchers suggested that although water-soluble allelo chemicals of *M. micrantha* inhibit seed germination and seedling growth of some plants, they also improve the availability of soil nutrients by increasing levels of carbon, nitrogen, nitrate and ammonia in the soil [53,54].

3.9 Impacts of Mikania in Nepal

Due to environmental conditions and habitats of Nepal, it is particularly sensitive to invasion of *Mikania* [55]. It is one of the worst weeds for agriculture, environment, human health and economy [56]. The weed severely smothers small trees, shrubs and herbs in the invaded region. The impact of invasion of Mikania is most serious in *Bombax ceiba* with high invasion in *Dalbergia sisoo* and *Acacia catechu* [5]. Heavy invasion of the weed has occurred in the buffer zone forest (50-80%) followed by core area (20-50%) in the CNPBZ [57]. About 52% of the native species of Chitwan National Park and its buffer zone are affected by *Mikania* invasion [58]. *Mikania* has influenced over 100 native plant species, particularly plants with a diameter at breast height < 30 cm in the buffer zone of Chitwan National Park [9]. *Mikania* has replaced species like *Lantana camara, Clerondendron viscosum, Pogostemon benghalensis* in CNPBZ and Arughans (local name), *Saccharum spontaneum, Typha angustifolia, Diplazium esculentum, Elymus spp, Imperata cylindrica* and *Clerondendron viscosum* in KTWRBZ. Forest edge, riparian vegetation, afforested land and grassland with sparse trees and shrubs in CNPBZ are being degraded due to high invasion of *Mikania* [57]. It has replaced the preferred fodder species of rhino and elephant such as *Mimosa rubicaulis* (not preferred by elephant), *Callicarpa arborea*, *Callicarpa macrophylla, Murraya koenigii*, *Holarrhena pubescens* by more than 60%. Shrestha and Tamang reported that *Mikania* has also affected Pater (*Typha angustifolia*), an economically important plant used for making household products (mat) in KTWRBZ and if the current trend continues the income generating source of local people will be highly impacted [30]. Also, the increasing rate of replacing of Niguro (*Diplazium esculentum*) by *Mikania* will lead impact on income source of local people. There is a need to supply medicine to the goat once in every 6 months in order to recover the health impacts caused by *Mikania* and apply chemicals in cultivated land to control *Mikania*. For these purposes, there is an extra expenditure to avoid the impact of *Mikania.*

3.10 Allelopathic effects

Studies suggest that allelopathy is a mechanism for the successful invasion by alien plant species [54]. Studies reported that the extracts of *Mikania* plants reduce the nitrogen content and biomass of legume cover crops and tomato seedlings significantly [59]. It was also evident that fresh weight and germination of *Asytasia intrusa*, *Chrysopogon aciculatas* and *Paspalam conjugatum* is significantly reduced by extracts of *M. micrantha* [60]. However, Ismail & Chong (2002) reported that seed germination, radical elongation and biomass production of *Lycopersicum esculentum* and *Brassica chinensis* were inhibited by aqueous extracts of *M. micrantha,* but *Zea mays* and *Vigna sesquipedelis* seedlings were not affected [61].

3.11 Uses

Economic gains due to *Mikania* are meager compared to the loss due to its infestation in various ecosystems. It is used as a fodder in many countries. Sheep preferentially graze *Mikania* in Malaysia and other cattle also relish it. It has been found that the weed is in practice of being utilized as a fodder in some parts of the state of India especially during summer when availability of grass is scarce. However, *Mikania* is known to cause hepatotoxicity and liver damage in dairy cattle. The study of has identified that *Mikania* can be utilized as green manure [62,63]. It was found to increase the yield of rice [64]. It is also stated that this vine can be used for making fertilizers [65].

It has been reported that various biochemical substances obtained from this weed exhibit anti-bacterial, anti-microbial, anti-diabetic, anti-dermatophytic, anti-proliferative, anti-stress, anti-cancer activities [66]. In fact, M. micrantha is rich in phytochemicals such as terpenoids (sesquiterpene lactones), alkaloids, flavonoids, steroids, reducing sugars, saponins, phenolics and tannins [67].Various studies have suggested that the neotropical vine shows inhibitory action against parainfluenza type 3 and respiratory synctia viruses [46]. It has great potential as a medicinal plant which may be exploited in the near future for human welfare [19].

In Assam (NE India), the Kabi tribes use leaf juice of *Mikania* as an antidote for insect bite, scorpion sting and to stop minor external bleeding. The leaves are also used for treating stomachache. Use of juice of *Mikania* as a curative agent for itches and also to reduce cholesterol, high blood pressure and glucose is reported from Malaysia. However, in all such cases therapeutic evidences are scarce or lacking. In Africa, *Mikania leaves* are used as a vegetable for making soups. The weed is used as a cover crop in rubber plantations in Malaysia. It is also planted on slopes to prevent soil erosion [68].

4. CONTROL METHODS

4.1 Mechanical

Attempts have been made to hand weed or to use slashing in plantations but this has been found to be ineffective and costly in labor terms [69]. All the stems need to be destroyed because of the weed's ability to grow from even the tiniest fragments [17]. Also, the creeping and climbing habits of *M. micrantha* enable it to penetrate into the crowns of bushes or trees where it is difficult to apply mechanical methods without damage to the crops. It seems that the manual cleaning is a never ending task because if a year is left to clean then the introduction of the weed by seeds or plant parts rapidly occur in the site from the adjoining area [70]. The single plant can release as many as 40,000 viable seeds every year and even the tiniest stem fragment is capable to grow a new plant in a moist area [7].

A systematic manual cutting could be an effective measure to control the spreading of *Mikania*, and would be more appropriate in community based forest management, where users are contributing voluntarily in forest management activities [59]. The study suggests that *Mikania* should be cut above the ground (1-1.5m) to disallow nutrient and moisture, and remaining part on the ground should be collected and used as mulching over adjacent creeper [9]. In this method, relatively low labor input is required as compared to other mechanical control. Managing the grassland without tree and shrub in protected area, the intensive and extensive use of land for the production of NTFP in community forest are found to be effective for the control of the *Mikania.*

Controlled fire checks invasion of *M. micrantha* better than the manual cutting. Controlled fire not only constrains the growth of *M. micrantha* but also promotes the growth of native grass species. Therefore, controlled fire could be an appropriate strategy to maintain the *M. micrantha* invaded grassland in the CNP and Koshi Tappu wildlife reserve [71]. Various studies suggest that the abundance of the alien species can be reduced in a small area after a continuous effort of manual cleaning (high labors and cost) but it is not feasible and sustainable in large areas. Even in a smaller area also community will not always remain active in lack of outside support. They loose their interest if they do not get any visible benefit, which was observed in the Dharahara Buffer zone Community Forest User Group of the area [10].

4.2 Chemical

Both pre-emergent and post-emergent herbicides are generally used for *Mikania* control. The dense growth habit of *M. micrantha* can be suppressed by the use of herbicides such as glyphosate, 2,4-D, napropamide and atrazine [72]. According to Hu and But (1994),germination of *M. micrantha* was effectively inhibited by 0.4% bentazone, and 0.2% picloram/0.4% bentazone was most effective against the growth of 25-, 45- and 60-day old seedlings. Furthermore, if the use of competitive crops is combined with a single application of bentazone, control can be increased to 90% for up to 3 months and is superior to the use of bentazon alone [41]. Although spray application of 2,4-D and glyphosate killed above-ground parts of this weed, it had fully regenerated by 3 months, while injection of 25% hexazinione and spraying of 75% sulfometuron methyl killed the whole plant [74]. Kumar reported that treatment with 0.8 kg gramaxone or 1 kg 2, 4-D amine/ha significantly reduced *M. micrantha* growth within 2-3 days of spraying, and there was no regeneration of the weed for up to 80 days afterwards [75].

All herbicidal applications should preferably be carried out before flowering and seed setting. It should also be borne in mind that though a single and thorough application of any one of these herbicides may control the weed for about a year, re-growth will occur in most areas through wind-borne seeds, especially after the onset of the monsoon. It may therefore be necessary to repeat annual applications for the next few years, depending on the severity of re-infestation.

4.3 Biological control

To combat the impact of the *Mikania*, various studies have been conducted around the world and realized that classical biological method is the cheap, environmentally safe and self-sustaining measure to control this weed. Research into biological control of *Mikania micrantha* Kunth (Asteraceae) started in 1978, concentrating on insect agents. Host specificity studies on the first agent, *Liothrips mikaniae* (Priesner) (Thysanoptera, Phlaeothripidae) from Trinidad were completed by 1982, and the thrips was released in the Solomon Islands in 1988 and, subsequently in Malaysia in 1990 [76]. Neither release led to establishment, and possible reasons for this are discussed, including the impact of generalist thrips predators and the effectiveness of different release strategies [77]. Other insect natural enemies were considered worth evaluating for host specificity and effectiveness, but failure of the thrips discouraged further investment.

In *M. micrantha* plants infected with *C .campestris*, the leaf number, stem length, bio mass, photosynthetic rate, transpiration rate, stomatal conductance, water use efficiency, chlorophyll content, and Fv/ Fm (ratio of variable fluorescence to maximal fluorescence) decreased 2 months after being parasitized by *C. campestris* [78]. *C. campestris* reduced the competitive ability of *M*. *micrantha*, leading to an increase in species richness and recovery of native communities [79]. However, despite numerous studies showing that *C. campestris* can reduce the size of *M. micrantha* infestations, land managers should be cognizant that *C. campestris* itself is a weed of at least 25 crops, including alfalfa (*Medicago sativa* L.), clover, fava bean (*Vicia faba* L.), beets (*Beta vulgaris* L.), and carrots (*Daucus carota* L.), leading to some substantial losses in yield [80]. As the plant grows over its host, there are limitations in using some chemical and manual control methods. In fact, due to the nature of crop losses and the difficulties in trying to control it, C. campestris was itself considered as a target for biological control [81].

A new initiative started in 1996, in collaboration with the Kerala Forestry Research Institute (India) and Vicosa University (Minas Gerais, Brazil), to assess the weed problem in the Western Ghats of India and to develop classical biological control based on exotic coevolved fungal pathogens as part of an IPM program. A rust pathogen, *Puccinia spegazzini* de Toni (Uredinales), has been selected as the prime candidate for introduction and a broad range of neotropical isolates is currently under glasshouse evaluation. The rust has demonstrated total specificity to *M. micrantha* (38 non-target species currently screened), is highly damaging (leaf, petiole and stem infections leading to cankering and death) and has a broad environmental tolerance [82]. *M. micrantha* is highly invasive in Asia, but only a minor ruderal species in its neotropical native range [83]. Thus, there is strong circumstantial evidence to suggest that coevolved natural enemies (probably specific to a single host taxon) play a significant role in regulating *Mikania* populations [84].

4.4 Control Attempts in Nepal

Attempts have been made at local level to control the invasion of this plant. For example, the District Forest Office of Morang district (Salakpur Range) has initiated manual cleaning of *Mikania* in about ten hectares of forest land two times a year, one before rainy season and the other before flowering time (winter season). The user groups are encouraged to replant native tree saplings in the area. About 3 hectares of another degraded forest marginal lands is also being planted by the user groups after manual cleaning of this plant. Similarly, Koshi Tappu Wildlife Reserve is planning to involve community to clean *Mikania micrantha*. Community is allowed to collect grasses from such areas against their efforts to control *Mikania*. However, this method of manual cleaning seems to be impracticable and uneconomic in heavily infected areas like Koshi Tappu. Again, monitoring and regular public involvement is a critical requirement to get good results. In Humsedumse community forest of Jhapa district, the Community Forest User Groups spent Rs. 70,000 in 2002 to clean *Mikania* [7].

5. CONCLUSION

The rapid spread of *M. micrantha* in Nepal is cause for great concern. Mile-a-minute is a belligerent vine that vigorously inhibits the growth of associated plant species, primarily by reducing the availability of light, as it very rapidly forms a dense cover over host plants, and also by secreting allelo chemicals in their proximity. The nature of invasion and its preferred habitat poses serious threat to the environment as to alter the ecosystem unfavorable for native organism as well as decrease the resources for the subsistence user. The weed is inciting a multiple of problems affecting environment and livelihoods. In addition, knowledge based on the weed control is limited and the invasion of weed will engender serious problems if early steps are not taken to resolve them. Thus, it is needless to say that *Mikania micrantha* should be categorized as "most serious weed" of tropical and sub-tropical parts of Eastern and Central Nepal and exigent actions to control the weed are to be taken. Also, high priority should be placed on strategies for early detection and rapid response, as appropriate for a rapidly invading species such as *M. micrantha*, and additional resources are needed to manage and reduce the spread of existing populations.

RECOMMENDATIONS

The study has brought up the following set of recommendations:

- Nepal government should give high priority and implement exigent remedial practices to control and manage the weed. More work is needed on finding likely effectiveness of potential biological control agents. Inadequate quantitative impact data and a measure of the scale of the problems are impeding appropriate actions at the national level.
- Avoidance of introduction of alien species in a new locality is the first and most cost effective approach which can be applied everywhere. Still, the western Terai is safe from the invasion of the Mikania weed. Therefore, regular field monitoring is obligatory for the early detection of introduction of the *Mikania* species in a new locality. Also, people should be educated and aware about the alien species.

- To tackle this weed, international cooperation and communication should be taken as key aspect and it is firmly suggested to be a member of CABI in order to get different aids for the control of the weed and other environmental facilitation. There is a need to establish cross-sectorial linkages on IAS, in order to facilitate cooperation and share experiences in appropriate control technologies.
- Local remedies such as using *Mikania* as green manure; application of engineering practices like leveling the slope; manual cutting before flowering season and plantation of favorable species like bamboo and cash crops like ginger and turmeric; biological control such as promotion of Akashbeli (*Cuscuta reflexa*), *Puccinia spegazzini*; scientific forest management like plant spacing, thinning of crown cover; and use for commercial purposes like paper production should be adopted for its mitigation.

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