Mimosa diplotricha: a review and synthesis of its problem and control options

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Abstract

Mimosa diplotricha C.Wright ex Sauvalle (=*Mimosa invisa* Mart.) (Mimosaceae) is a perennial weedy shrub of neotropical origin and a serious biotic threat in its invasive range. Despite its invasiveness and associated problems, there are surprisingly few reviews on this weed. This paper, therefore, reviews the existing but scattered literature on the invasion history and negative impacts of *M. diplotricha* in different ecological systems in its introduced ranges. Following the introduction of *M. diplotricha* into Indonesia and Australia in the early nineteenth century, the weed has since rapidly spread into many other countries in Asia, Africa and Oceania. It is known to be present and/or invasive in more than 14 Asian (e.g. India, Thailand, the Philippines) and 17 African countries (e.g. Nigeria, Ethiopia, Kenya) and more than 16 countries in Oceania including Australia and Papua New Guinea, with some serious negative effects on agriculture, biodiversity conservation and livelihoods. Landowners, locals and peasants in invaded areas employ physical/mechanical, cultural and chemical control methods to manage *M. diplotricha*, but these methods are unsustainable, costly and largely ineffective. The first biological control of *M. diplotricha* worldwide began in Australia in the 1980s with the release and establishment of *Heteropsylla spinulosa*, a sap-sucking bug that significantly reduced densities of the weed. This bug was subsequently introduced to many Islands in Oceania where it established and reduced the densities of the weed. This paper discusses the problems of *M. diplotricha* in different ecosystems in invaded areas, control options and gives recommendations for the sustainable management of the weed in Asia and Africa.

Keywords: *Mimosa diplotricha*, invasive alien plant, introduction and impact, management strategies, weed biocontrol, *Heteropsylla spinulosa*

Review Methodology: We reviewed the literature by searching both academic and grey literature in Google Scholar and ISI Web of Science. Published papers, conference proceedings, CABI Invasive Species Compendium and dissertations, some of which are not available online, were also assessed. Prior to a systematic review of the reference lists in the acquired papers, we sorted all data sources and included only articles relevant to the invasion history, impact and control of *M. diplotricha* in West and East Africa, Southeast and South Asia and Oceania. This was supported by discussions with members of the International Organisation of Biological Control (IOBC), who are experts on certain invasive plant species.

Introduction

Mimosa diplotricha C. Wright ex Sauvalle (=*Mimosa invisa* Mart.) (Mimosaceae) is a fast-growing leguminous perennial shrub of neotropical origin that is currently invasive in parts of East and West Africa, South and Southeast Asia and Oceania [1–4]. *M. diplotricha* is commonly known as the giant sensitive plant, creeping sensitive plant and various local names also exist wherever it has been introduced [5]. This weed is still called *M. invisa* Mart. in some parts of Africa and Asia [6, 7].

M. diplotricha is and remains a huge threat to natural and semi-natural ecosystems in its introduce ranges, where it is known to negatively impact a variety of agricultural

crops, livestock production, biodiversity conservation and livelihoods [1–4]. However, the weed is also known to provide some benefits in its invasive ranges especially in Asia (India, Sri Lanka, Indonesia, etc.) where it is used as a cover crop and green manure in plantations to improve soil biological, chemical and physical properties [8–11]. Despite the positive attributes of the *M. diplotricha*, it is still seen as a menace that needs to be controlled and managed in all countries where it is invasive. The rapid expansion and spread of *M. diplotricha* in its invasive ranges [1, 2, 12, 13] warrant a general review on the threats posed by this thorny leguminous shrub in different ecosystems.

Understanding the effects of *M. diplotricha* on agriculture, biodiversity, livelihoods and human well-being is essential for developing sustainable management strategies and guiding policy formulation. This paper, therefore, reviews the existing but scattered literature on the invasion history and negative impacts of *M. diplotricha* in different ecological systems in invaded areas (West and East Africa, South and Southeast Asia and Oceania). This paper also discusses the management and control initiatives or options undertaken in these areas and gives recommendations for the sustainable management of the weed in Asia and Africa. This paper is expected to raise awareness on the implications of the uncontrolled spread of the weed in the tropics and stress the need for an effective national or regional control programmes.

Description, biology and ecology of *Mimosa diplotricha*

Mimosa is one of the largest genera of Mimosoid legumes with over 500 species [14, 15]. *M. diplotricha* is an annual shrubby and scrambling climber that often forms and spreads impenetrable, tangled, dense thickets and can sometimes behave as a biennial or perennial leguminous vine [1, 2, 16, 17].

The main stalk has up to eight pairs of sub-leaf stalks and each sub-leaf stalk may bear as many as 20–30 opposite leaflets, which are small, bright green, alternate, bipinnate and sessile and are about 6–12 mm long and 1.5 mm wide [1, 2]. The stem is four angled, woody decumbent base with re-curved thorns (3–6 mm long), up to 3 m in height. The pinkish-violet flowers occur in globose heads about 12 mm in diameter and may occur singly, in pairs or threes on individual stalks originating in the axils of young leaves. Although flowering occurs throughout the year [1, 2, 18], most occurs in late wet season [16]. The smooth light brown seed is flat, hard, ovate and about 2.5 mm long [1]. It is a prolific seed producer that can produce up to 20,000 seeds/m^2 per year and a single plant can produce up to 10,000 seeds per annum [1, 19, 20]. Seeds are retained in spiny pod segments and are adapted for dispersal by floating on water as well as by spiny segments adhering to animal fur and clothing. The movement of vehicles and machineries and the transportation of contaminated plants or soil materials can also assist the spread of the seeds. Some of these seeds may germinate immediately while others may remain in the soil for several years before germination. The seeds can remain dormant for up to 50 years [21].

M. diplotricha grows best where fertility, soil and air humidity are all high and dies away in prolonged dry seasons. The plant commonly grows in crops, plantations and pastures, as well as on disturbed moist wastelands, drains and watercourses in tropical and subtropical regions and seems to prefer open areas and disturbed ecosystems such as forest fringes and roadsides with lots of sunlight. The weed is heliophytic in adaptation and cannot grow under a closed canopy but can grow under a wide range of altitude (0–2000 m asl). In Nigeria, most germination occurs at the beginning of the wet season (between March and May) but seeds may germinate at any time of the year when the suitable conditions of moisture and temperature are met. The ability of the plant to tolerate a wide range of soil *p*H, soil types, vegetation types and altitudinal regimes has been documented [4, 7, 22].

Introduction and spread of *Mimosa diplotricha*

Although the nativity of the *M. diplotricha* has been traced to Brazil [1, 2], its natural habitat range in the Americas stretches from Mexico to Argentina including the Caribbean Islands [1, 2, 14]. The weed is now known to be invasive or present in many tropical countries in Africa, Asia and Oceania [1, 2, 5]. The invasion history of *M. diplotricha* is shown in Fig. 1. Outside of its native range, *M. diplotricha* was recorded in Indonesia on the Island of Java in 1900 from where it spread into other countries in Asia [23, 24]. As of the 1960s and 1970s, *M. diplotricha* was already seen as a menace in Thailand, Cambodia, Sri Lanka, Malaysia, the Philippines, Taiwan, Vietnam and India [1, 2, 25, 26]. *M. diplotricha* was introduced to Taiwan in 1965 as an ornamental [26]. The weed is thought to have spread into Laos, Myanmar, East Timor, Singapore and China between the 1980s and 1990s where it is now invasive or present in large parts in these countries [1, 2, 5]. In Oceania, the first record of the weed dates back to the 1920s when *M. diplotricha* was known to have been present in a location near Tully in Queensland, Australia in 1929 [2]. The weed was first recorded in Fiji in 1936 and first reported in Western Samoa in 1972 [2]. As of the 1970s and 1980s, *M. diplotricha* had spread to Papua New Guinea (PNG), French Polynesia, Guam, New Caledonia, Samoa, Palau, Vanuatu, Cook Islands and Solomon Islands forming dense tangled, thorny clumps that smother other vegetation [1, 2, 5]. In the late 1980s and early 1990s, the weed was reported to be invasive and present in Niue, Northern Mariana Islands and Wallis and Futuna Islands [1, 2, 5].

The timing and source of introduction of *M. diplotricha* into Africa is unknown but the weed is thought to have been on the continent for over three decades [1, 2, 4]. The weed

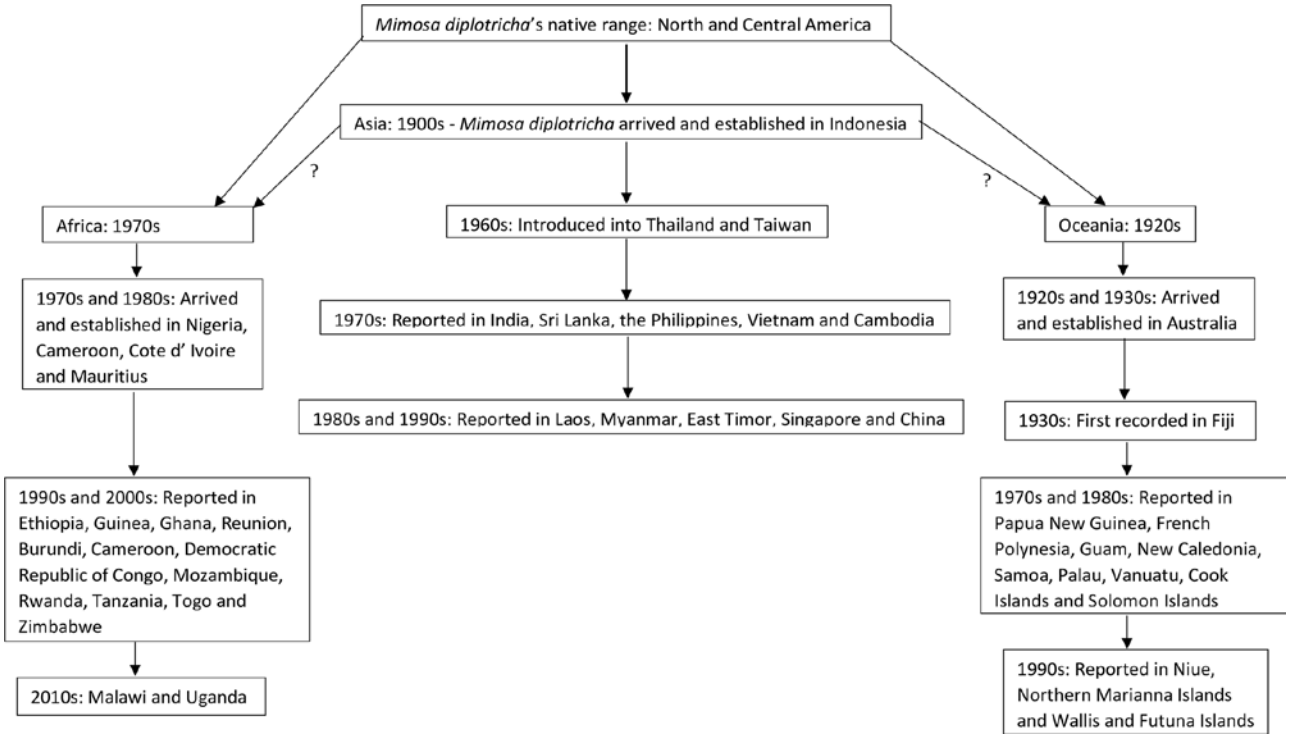

Figure 1. The invasion history of *Mimosa diplotricha*.

was reported as a noxious pest in Nigeria, Cameroon, Cote d' Ivoire and Mauritius in the 1970s and 1980s [1, 2]. Between the 1990s and 2000s, *M. diplotricha* was reported to be present or invasive in Ethiopia, Guinea, Ghana, Reunion, Burundi, Democratic Republic of Congo, Mozambique, Rwanda, Tanzania, Togo and Zimbabwe [1, 2, 5, 13, 27]. A recent report published in 2017 documented the invasiveness of *M. diplotricha* in Uganda and Malawi [13].

In Australia, *M. diplotricha* is confined to the north Queensland coastal region between Ingham and Cooktown, around Mackay, and at Brisbane [16, 21], and it is thought to have the potential to spread to the Northern Territory and Western Australia [28]. In Western Samoa, it is estimated that 85% of the villages on the island of Upolu are infested with the weed [29]. It commonly forms clumps up to 20 m in diameter in the Markham and Ramu Valleys in Papua New Guinea [19]. On Peninsular Malaysia, it occurs in the States of Perlis, Kedah, Seberang Perai, northern Perak, Selangor, Malacca, Negeri Sembilan and Johore [30]. In Nigeria, *M. diplotricha* is invasive in the entire southern states in Nigeria and maintains some presence in the north-central region of the country [4]. Seed dispersal is through running water and carried in animal fur, clothing, vehicles, agricultural implements and machinery. Anthropogenic influences, such as the movement of humans and machinery, trade, infrastructure development—such as road construction—and tourism across the 'open borders' between countries in Asia, Africa and Oceania may have been fundamental drivers that have facilitated the widespread invasion of *M. diplotricha* in the tropics. In addition, the high reproductive capacity of the weed, readily dispersed propagules, its ability to outcompete other plant species for both light and space and adaptation for growth in a range of soil types and climatic conditions may be associated with its overall invasion success in new areas. Given that *M. diplotricha* can spread through contaminated crop seeds or through deliberate introduction as a forage or ground cover, it has the potential to be introduced, to spread and become a major weed in many tropical countries that lack the capacity to control or manage the weed.

Impact of *M. diplotricha*

M. diplotricha is a serious weed that has been implicated in the transformation of the integrity of many natural and semi-natural ecosystems, leading to a decline in biodiversity, agricultural production and biodiversity conservation efforts in the Pacific, South and Southeast Asia, Australia and in several countries in West and East Africa [1–4, 6, 31]. In countries where *M. diplotricha* is invasive, the weed is commonly seen in arable croplands, plantation crop farms, fallow lands, roadsides, abandoned lands and deforested areas. The weed rapidly invades new areas and smothers pasture and forage crops in tropical and subtropical countries, reducing crop yields. For example, in Nigeria, Alabi *et al.* [6] showed that interference of the weed negatively affected the growth parameters of cassava, one of the most widely grown staple crops in Nigeria. In the same study, high populations of *M. diplotricha* was shown to reduce storage root yield in cassava and accounted for

85% reduction in crop yield. Locals in Benin City, Nigeria and Ecologists and Crop Scientists consider *M. diplotricha* as the most noxious weed in that part of Nigeria where it has invaded farms, plantations, abandoned buildings and roadsides [4, 32]. In Papua New Guinea, *M. diplotricha* is known to negatively impact on the growth and yield of sugarcane and infestation by the weed resulted in increased harvesting time of the crop [3]. The estimated total cost of lost time due to *M. diplotricha* interference was US$320,000 per year [3].

M. diplotricha is a very serious pest of oil palm and coconut (especially at the nursery stage) in Nigeria [4] and a serious weed problem in rubber and coconut plantations in Papua New Guinea. It is known to pose a serious weed problem to the production of many crops such as rice in the Philippines, Indonesia, Thailand, Vietnam and Laos [18, 33]. It is considered a pest of sugarcane in Papua New Guinea, Taiwan, Philippines, Australia and India; tomato in the Philippines; rubber in Indonesia and Malaysia; soya beans, citrus, maize, apple, cassava and tea in Indonesia; banana in India and pineapple in the Philippines [1, 34–39]. It is seen as potentially the worst weed in plantations and arable lands in the Philippines and Fiji [1]. The weed poses a serious threat to tropical pastures in Australia and the Philippines and the Pacific Islands [1, 29, 40, 41]. On cattle ranches in the Ramu-Markham Valleys, in Papua New Guinea, up to US$130,000 was spent on the chemical control and slashing of the weed [42]. The prickly thorns of *M. diplotricha* make control of infested farms and harvesting of crops very difficult, hence invasion always results in increased production and management cost and decreased productivity in many agroecosystems. Losses incurred by farmers due to the suppression of staple crops by *M. diplotricha* have been described as overwhelming and this has forced numerous farmers to abandon their farms or plantations in Nigeria (personal observation).

M. diplotricha thickets interfere with the communities of natural and semi-natural ecosystems and may constrain the movement of wildlife and humans due to their ability to smother other plants and numerous sharp recurved prickles. Infestations by *M. diplotricha* hinder the regeneration, reproduction and growth of native species in infested areas and consequently result in the gradual loss of biodiversity [22, 43]. In southern Nigeria, *M. diplotricha* compete with indigenous plant species and replace non-native species such as *Chromolaena odorata* (L.) (Asteraceae) [44]. In India, Sankaran [45] reported that *M. diplotricha* smothers other invasive plants such *C. odorata* and *Mikania micrantha* H.B.K. (Asteraceae) and establishes itself over them. The movement of rhinoceros (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*), tiger (*Panthera tigris*) and swamp deer (*Cervus duvauceli*) has been reported to be hampered by dense stands of *M. diplotricha* in Kaziranga National Park in northeast India [22]. The avoidance of *M. diplotricha* by livestock during grazing is thought to be due to its sharp and curved thorns and/or the presence of mimosine (a non-protein amino acid), which is toxic to herbivores if ingested as it can cause vascular endothelial damage, necrosis of heart and liver and anaemia in cattle [22]. Overall, *M. diplotricha* is known to pose a major threat to agricultural productivity (crop and livestock production) and biodiversity conservation, thereby negatively affecting the quality of lives of locals and the integrity of ecosystems in invasive ranges.

However, *M. diplotricha* is also known to provide some benefits in its invasive ranges. It has been reported by local people and scientists in Asia to have several beneficial attributes. *M. diplotricha* is a nitrogen (N) fixer [41] and in India, Sri Lanka, Indonesia and other Asian countries, the weed has been frequently used as cover crop, green manure and soil renovator to add soil nitrogen and organic matter and to reduce soil erosion [1, 8–11, 40, 46]. In Benin City, Nigeria, and elsewhere the weed prevents cattle from invading arable farms (personal observation). In southern Nigeria, *M. diplotricha* displaces more troublesome weeds like *Imperata cylindrical* (L.) (Poaceae) and other invasive plants such as *C. odorata* and *Tithonia diversifolia* (Hemsl.) (Asteraceae). The insecticidal activities of the root and leaf extracts and powders are increasingly being recognised [47, 48].

Control options

Because of the problems of *M. diplotricha*, it has remained a subject of several eradication and control programmes in some countries (e.g. Nigeria, Australia and some Pacific Islands) [3, 31, 49, 50, 51]. In many countries where *M. diplotricha* is invasive, several conventional methods such as cultural, mechanical and chemical control methods were adopted and are still being used in managing the weed (Fig. 2). This section discusses the conventional control options and biological control efforts undertaken in the world.

Cultural control

Parsons and Cuthbertson [16] suggested that sugarcane fields with heavy infestations of *M. diplotricha* may need to be quarantined for a number of years and further advised that destroying the crop is key to preventing further spread of this weed. In upland rice farms in the Philippines, treating *M. diplotricha* infestation with 5 t/ha of fresh *Gliricidia sepium* green manure plus 5 t/ha of fresh *Senna spectabilis* mulch significantly reduced the weed biomass [52]. Chadhokar [53] reported that discouraging overgrazing can limit the spread and infestations and thus control may be more realistic in areas where animals are restricted from grazing.

Mechanical/physical control

The use of physical means, such as weeding with crude implements—shovels, hoes and cutlasses—has been

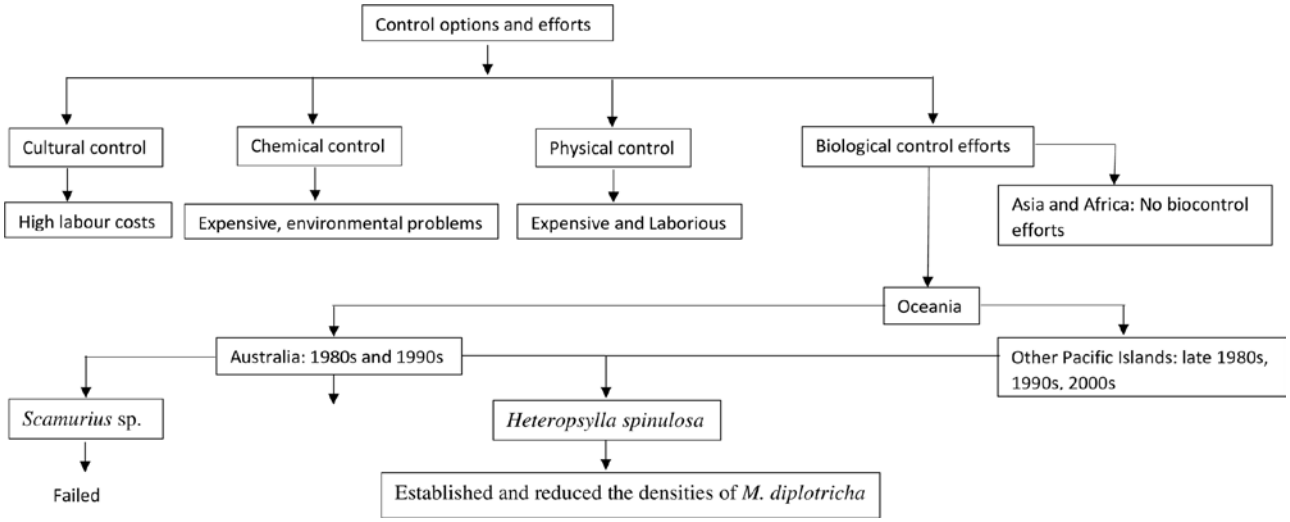

Figure 2. The control of *Mimosa diplotricha* in Africa, Asia and Oceania.

widely adopted in managing *M. diplotricha* in Nigeria and elsewhere. Hand weeding is possible when the plants are young or in small infestations, but the prickles or thorns on the vines can cause serious injuries to humans and animals. In Nigeria, the use of hand-held hoe to remove the weed is a popular and remains an effective method of control among peasants. However, most farmers complain that the thorns on the stems and pods reduce the efficiency of manually controlling the weed. The vigorous regrowth from the root crown and the rapid and prolific seedling development make slashing or burning ineffective methods of control [2, 3, 16]. Despite the efficiency of mechanical control methods such as using hand-held hoes to remove the weed [54], this method of control is laborious, time wasting and impractical in invasive conditions especially in developing countries where most farmers are predominantly peasants.

Chemical control

Farmers and landowners in invaded countries use a host of herbicides such as isoxaflutole, atrazine, diuron, paraquat, etc. (applied singly or as a mixture) have been used in the control of *M. diplotricha* [3, 31, 49, 50, 51]. In some Pacific Islands, paraquat + diuron applied postemergence have provided good control of *M. diplotricha* and 2,4-D + atrazine has been applied as an overall spray especially in pasture situations to control young to semi-mature stands [51]. In Nigeria, an empirical research showed that atrazine + metolachor, bentazon + propanil and acetochlor + atrazine controlled *M. diplotricha* satisfactorily but reduced the yield of cassava compared to hand-weeded control [31]. By applying primextra, a formulated mixture of atrazine and metolachlor followed by hand weeding, a considerable amount of control of the weed was achieved in cassava fields in southeastern Nigeria [50]. Despite the efficiency of chemical control methods in the management of *M. diplotricha* especially in large-scale farming systems, it is expensive and not environmentally friendly. Therefore, its use is not sustainable. A combination of other weed control methods such as chemical, mechanical and biological control may be more effective [4]. It should be noted that some of these herbicides (e.g. 2, 4-D and Paraquat) used to control M. diplotricha are not allowed to be used in some countries.

Biological control

The first biological control programme for the management of *M. diplotricha* commenced in Australia in the early 1980s with the identification of over 70 insect species and 2 fungal species (as potential biocontrol agents) in Brazil [4, 24]. Of the over 70 species, only 3 proved to be promising biocontrol candidates. Following the failure of the Coreid bug, *Scamurius* sp. (Hemiptera: Coreidae) to establish after it was released in Australia in 1988 [55], another Hemipteran species, *Heteropsylla spinulosa* Muddiman, Hodkinson and Hollis (Hemiptera: Psylloideae) was released in 1988–1989 and immediately established [29]. Within 2 years of commencing field releases, the tiny sap-sucking bug widely dispersed and caused severe damage to *M. diplotricha*. Feeding (sap-sucking) activities by both immatures (nymphs) and adults on leaflets, rachises and growing tips result in stunted growth and deformed plants. Females lay about 50 eggs in their lifetime and the nymphs pass through five instars and become adults in 18–20 days. The insect is able to complete eight generations per year [56]. Feeding damage caused by *H. spinulosa* resulted in dense clumps of the weed reduced to small masses of bare stems with stunted growth tips that result in death in some cases and this allowed other plant species to re-establish in Australia [57]. This Psyllid bug

was shown to reduce seed production in *M. diplotricha* by up to 85% and 100% [57].

H. spinulosa was introduced from Australia into Western Samoa in 1988–1989 and Papua New Guinea in 1991 [29, 42] where it is known to have established and reduced the biomass of *M. diplotricha* [3]. This insect is thought to have exerted a spectacular control over *M. diplotricha* in Papua New Guinea [3]. Following its introduction into several other Pacific Islands such as Cook Islands, Fiji, Palau, Pohnpei, Samoa, Solomon Islands and Yap, *H. spinulosa* has not only established but provided a sustained suppression requiring little or no additional efforts to manage this weed [3]. Most areas cleared of *M. diplotricha* by *H. spinulosa* in these island nations have been taken over by the native plants. Due to the ability of *H. spinulosa* to cause severe stunting and distortion of leaves and growing tips and its overall impact on *M. diplotricha*, this biocontrol agent should be considered for the control and management of *M. diplotricha* in Nigeria, India, Thailand and other countries where the weed is problematic. Such control attempts would benefit from international collaborations between institutions in these invasive ranges and a host of others countries (e.g. Australia, Papua New Guinea) that have successfully initiated biocontrol programmes against the weed.

Attempts to release a third biological control candidate, *Psigida walkeri* (Grote) (Lepidoptera: Citheroniidae), were unsuccessful because this leaf-feeding moth failed host specificity screening [56]. In the Philippines, a fungus isolated from *M. invisa* (=*M. diplotricha*), *Fusarium pallidoroseum,* which caused high damage to *M. invisa,* was rejected as a potential biocontrol agent because the fungus culture filtrates of *F. pallidoroseum* caused disease symptoms on a broad range of plant species [58]. In Queensland, Australia, an indigenous stem-spot fungus, *Corynespora cassiicola*, is known to have exercised a degree of control on *M. diplotricha*. The fungus is thought to be widespread and specific to *M. diplotricha* and causes defoliation and dieback [21].

Conclusion

Since the introduction of *M. diplotricha* into Indonesia and Australia in the early nineteenth century, the weed has spread extensively into many countries in Asia, Africa and Oceania, especially in the last eights decades. Apart from the invasive characteristics of *M. diplotricha*, the continuous spread of, and invasion by, this weed in countries where it is invasive has been due to: (i) the increased human disturbances associated with the recent economic growth and infrastructural development; (ii) lack of an integrated control and management programme; (iii) lack of a sustained biological control programme especially in Asian and African countries; and (iv) its use as a cover crop and green manure in plantations to improve soil biological, chemical and physical properties in some Asian countries. Given that *M. diplotricha* has attained a problematic status in agricultural lands and commercial plantations as well as being a perceived threat to biodiversity conservation and human livelihoods in its invasive range, it would be justified to reduce its competitiveness in order to limit its menace in both natural and semi-natural ecosystems. Because conventional methods of controlling *M. diplotricha* are unsustainable and impractical, I recommend that Asian and African countries where the *M. diplotricha* is invasive should prioritise the release of *H. spinulosa,* which can effectively inflict extensive but selective damage on this invasive alien weed. If the spread and impact of *M. diplotricha* in Asian and African countries and Pacific Islands are to be curtailed and eventually reversed, several initiatives for control and management are required at both national and regional levels. These include: (i) initiation and sustenance of an effective biological control programme in affected countries and regions; (ii) creation of sustained public awareness about the weed problem especially in areas that are sparsely infested or in un-infested areas that have the potential to become infested; and (iii) the development of a coordinated and integrated control and management plan for *M. diplotricha* on a national and regional scale.

Summary points

- From its native range in the Americas, *M. diplotricha* was introduced into Indonesia and Australia in the early nineteenth century. The weed is now present in over 14 countries in Asia, 17 countries in Africa and many islands in the Oceania.
- *M. diplotricha* is a threat to the diversity of extant vegetation and impacts negatively on agriculture, food security and livelihoods. It is considered one of the worst invasive species in many countries where it is invasive.
- Control strategies have historically relied on conventional means such as the use of hand hoe to uproot entire plants, slash and burn, and the seldom use of chemical herbicides. These methods are, however, laborious and costly in the long term and are unsustainable.
- Biological control of *M. diplotricha* worldwide first began in Australia in the 1980s with the release and establishment of *H. spinulosa*, a sap-sucking bug that significantly reduced densities of the weed. This bug was transferred to many islands in Oceania where it established and reduced the densities of the weed.
- Because the ecological and economic impacts of *M. diplotricha* in many countries in Asia and Africa are too significant to be ignored, it is suggested that a coordinated biological control programme should be initiated and sustained against the weed.

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