

## ***Mimosa pigra* L.: A dangerous invasive weed in Vietnamese agro-ecosystems**

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**Abstract :** *Mimosa pigra* was reported to occur for the first time in Moc Hoa district, Long An province in Vietnam in 1979. Since then, it continues to propagate, disperse and spread in many places within the country. *Mimosa pigra* is an aggressive invader in the places of non-vigilance by the people such as roadsides, dikes, field bunds, canals of irrigation and drainage and waste land. It invades strongly along the rivers, surrounding large reservoirs, wetland reserves or parks. In some cases it is reported that this dangerous weed has invaded agricultural fields. A lot of effort has been carried out to control *Mimosa pigra* so far but with little success. The strong effort to check the invasion of this dangerous weed is needed in the future.

**Key words :** *Mimosa pigra*, invasive weed, wet land, Tram Chim National Park.

### **I) Introduction**

Vietnam is situated in Southeast Asia. It has borders with China to the North and Laos and Cambodia to the West. To its South and East is the Pacific Ocean. Its climate is dominated by two monsoon cells, a wet cell (June – November) and a dry cell (December-May). Northern winters can be cold while the South is warm year round. Latitude and topography exert localized influence on climate patterns. Vietnam has a land area of 320,000 km<sup>2</sup> and a coastline of 3,260 km. Three quarters of its territory is covered by hills and mountains with elevations between 100 and 3400 m, while the plain areas include two major river deltas, the Red River delta in the North and the Mekong River delta in the South. The lowlands are extremely fertile and densely populated and most of Vietnam's agriculture and industry are concentrated there. Vietnam has a tropical monsoon climate, although regional climate variations are considerable due to the length of the country and the diverse topography. Annual mean temperature ranges between 18°C to 29 °C, while mean temperatures during the coldest months vary between 13°C and 20 °C in the northern mountains and between 20°C and 28 °C in the tropical South. In most parts of the country, annual rainfall ranges between 1,400 mm and 2,400 mm, but can be as high as 5,000 mm or as low as 600mm on average in some regions. Rainfall is unevenly distributed throughout the year, with about 80-90 percent of the rainfall concentrated in the rainy season, causing floods and frequent landslides. The number of rainy days in the year is also very different between the regions and ranges from 60 to 200 (Chaudhry and Ruyschaert, 2008)

Vietnam has a dense systems of rivers with 9 big catchments including Hong- Thai Binh ( 92,246 km<sup>2</sup> within Vietnam territory ), Mekong ( 70,520 km<sup>2</sup> ), Dong Nai ( 36,261 km<sup>2</sup> ), Da ( 25,500 km<sup>2</sup> ), Ca ( 21,230 km<sup>2</sup> ), Ma-Chu ( 17,600 km<sup>2</sup> ), Ba ( 13,800 km<sup>2</sup> ), Ky Cung- Bang Giang ( 11,200 km<sup>2</sup> ), Thu Bon ( 10,350 km<sup>2</sup> ) and other smaller catchments . Origin from Tibetan plateau in China , Mekong river has the length of 4,800 km and goes across 6 countries including China, Myanmar, Laos, Thailand, Cambodia and Vietnam before coming out to the Pacific ocean . Total its catchment is 795,000 km<sup>2</sup>. Tonle Sap Great Lake in Cambodia is the biggest fresh water lake in Southeast Asia. It keeps water in rainy season and releases gradually downward in dry season. *Mimosa pigra* infestation around the great lake, wetlands

along the Mekong river and its flood plain is very serious (Samouth, 2004) . Their seeds move along with flood water to downstream areas in Vietnam.

Between 17,000 and 7,000 years before common era (BCE), de-glaciations raised average sea levels by 9mm annually-a total of 90 m. Few societies were as affected as those of littoral Southeast Asia, where it has been estimated that 50% of inhabited lands were submerged. ( Dap, 1999). Vietnam is one of five countries in the world which is badly affected by global warming interms of the rise of sea water level . In the scenario of 1-m increase in sea level , 40,000 km<sup>2</sup> of land will be submerged mainly in the Mekong River delta.

More than 10,000 years back , this land was submerged . In the future , Vietnam territory with dense network of rivers will be affected by submergence again by climatic change . This will create large areas of wet land which are conducive for the growth and spread of very dangerous weed – *Mimosa pigra* .

## **II) Biology of *Mimosa pigra***

### **1) Description**

When mature, *Mimosa pigra* is an erect, much branched prickly shrub reaching a height of 3m to 6m. Stems are greenish at first but become woody, are up to 3m long, and have randomly scattered. Leaves are bright green, 20cm to 25cm long and bipinnate, consisting of about 15 pairs of opposite primary segments 5cm long with sessile, narrowly lanceolate leaflets that fold together when touched or injured and at night. The flowers are pink or mauve, small, regular and grouped into globular heads 1cm to 2cm in diameter. The heads are borne on stalks 2cm to 3cm long, with two in each leaf axil, while the corolla has four lobes with eight pink stamens. The fruit is a thick hairy, 20-25 seeded, flattened pod borne in groups in the leaf axils, each 6.5cm to 7.5cm long and 0.7cm to 1cm wide. The fruit turns brown when mature, breaking into one-seeded segments. The seeds are brown or olive green, oblong, flattened, 4mm to 6 mm long, and 2 mm wide (Walden *et al.*, 1999).

### **2)Life cycle and its invasive potential**

Seeds are produced in individual segments of seed-pods that ‘burst’ apart when mature. Under optimal conditions annual seed production may reach up to 220,000 per plant. A study carried out within the Mekong Delta found that the average number of seeds in the topsoil was 100 seeds per meter squared. In contrast, an average of 12,000 seeds per meter squared was reported for a mimosa-infested area in northern Australia (Lonsdale 1992). Plants mature quickly and can set seed in their first year of growth . Flowering may begin 6 to 8 months following germination. Flowers are bee-pollinated and possibly wind-pollinated. Plants are thought to be self-compatible. Flowers develop in about 7 to 9 days, and seed pods in about 25 days. *Mimosa pigra* fruits and flowers all year round in the Mekong Delta, but its main fruiting season occurs during the dry season (December to May). Seeds are extremely hardy and can remain dormant for more than 15 years depending on the environment. For example, half of a seed population was no longer viable after 99 weeks at a depth of 10 cm in a light clay soil, while a similar loss in viability was observed after only 9 weeks in heavier cracking clay. In sandy soils the lifespan of seeds may be much longer. Dormancy of seeds in the soil is broken by expansion and contraction of the hard seed-coat by temperature changes ranging from about 25–70°C. Seeds buried deeper than 10 cm generally do not successfully germinate unless brought to the surface (Walden *et al.*, 1999).

### **3) Invasive pathway to new locations and local dispersal methods**

*Mimosa* is a native plant of Central America and probably entered the Northern Territory of Australia prior to the 1890s through the Darwin Botanic Gardens (Lonsdale *et al.*, 1995). It remained a minor localized weed for over 100 years as it was confined to the Darwin area. However, mimosa seeds eventually spread and were found upstream along the Adelaide River, where upon reaching the wet-dry tropics north of Darwin, it increased dramatically with the help the feral water buffalo (Lonsdale *et al.*

1995, Lonsdale 1993). *Mimosa* also spread in ensuing years, especially during the 1970s, covering more than 800 km<sup>2</sup> of wetlands in subcoastal Northern Territory by 1989. Infestations can nearly double in just over one year and on average every 6 years. By 1981, much of the Adelaide River flood plains were covered by nearly monospecific stands (Lonsdale et al. 1995, Lonsdale 1993). *Mimosa* favours a wet-dry tropical climate and grows in open, moist sites such as floodplains, coastal plains and river banks. For example, in the Mekong Delta, Vietnam, where it is a serious weed with an annual rainfall levels may reach up to 2,200mm. It may not be a major problem in regions with an annual rainfall of less than 75mm or greater than 2,250mm. In both Australia and Vietnam it prefers to invade seasonally inundated grassland. It is more likely to colonise and eventually cause problems in disturbed areas. This is due to the ability of *mimosa* seeds to establish rapidly on bare soils, which lack competitive pressures imposed by other seedlings. It is common along the edges of reservoirs, canals, river banks and roadside ditches, and in agricultural lands and overgrazed flood plains. In Vietnam it is typically found along the edge of both natural and manmade water bodies and along roadsides. Seeds pass unharmed through the digestive tract of animals resulting in rapid spread. The seed segments are covered with bristles that enable them to adhere to animals and clothing. People transport the seed on vehicles, equipment and clothing. The seeds are dispersed in soil and mud. For example, *Mimosa pigra* seeds were probably brought into U Minh Thuong National Park, Vietnam, via contaminated construction sand. Seeds pods are buoyant, and may be dispersed by flood waters and water currents. Fast-moving water in channels is perhaps the most important seed dispersal mechanism within the Mekong Delta. Water facilitated spread has also been a notable natural form of spread in northern Australia. Heavy flooding, in combination with overgrazing of rangelands, catalysed the spread of *Mimosa pigra* through these Australian flood plains during the 1970s (Walden *et al.*, 1999).

#### **4) Current situation of *Mimosa pigra* in Vietnam**

The origin of *Mimosa pigra* is Central America. It was brought to Asia at the end of 19<sup>th</sup> century. At the early step, they invaded gradually and it was recorded for the first time in 1979 in Moc Hoa district, Long An province in the the Mekong Delta of Vietnam (Triet et al., 2004). Now this weed has been spread in many places through out the country. *Mimosa pigra* has been considered as a dangerous weed recently in the Mekong Delta of Vietnam. Although *mimosa* was first introduced into Vietnam in the 1970s, it has continued to spread along the roadsides and fallow highland areas in the northern and central provinces. The surveillance conducted by the National Institute of Plant Protection (NIPP), in 89 districts and 1,169 villages of eight provinces in Central Coast and Central Highland regions, showed that there were only 31.3% of surveyed sites at district level and 18.1% at village level infested, with the total area of *mimosa* being 680 ha. It was mainly concentrated along the roadsides in Quang Nam and in highland areas of Gia Lai Province (Cam *et al.*, 1997). It has nearly the same status in the northern provinces, where *mimosa* was occasionally found growing in a few locations. The major concentration was observed around some lakes, such as Dong Mo, Nui Coc, Ba Be, Thac Ba, Dai Nai and others. Recently *mimosa* was reported to have spread to a large area of fallow highland in Quang Binh Province. This species is very popular in public land such as: protected areas, roadsides, banks along rivers, but infests slowly in private land. This may be due to the vigilance of land owners to take care of their property carefully. It has become serious weed in low wet land in Tram Chim National Park, Cat Tien, Yok Don, Bien Lac Lake, Tri An Lake.

Although, this weed occurs in many places in Vietnam, but more research have been done in the Mekong Delta and the South East as compared to other regions.

##### **a) Mekong River delta**

The Tram Chim National Park locates in Tam Nong district, Dong Thap province of the Plain of Reeds. Its latitude is 10°40' – 10°47' North and the longitude of 105°26' - 105°36' East. Before 1980, *Mimosa pigra* was observed in small pocket in Tan Hong and Hong Ngu districts. After that it invaded the other districts of Dong Thap province such as Thanh Binh, Tam Nong and finally entering the Tram

Chim National Park. It infested the Tram Chim Park very fast. In 1984-1985, it was recorded for the first time. The area reached 150 ha in 1999, and 490 ha in May 2000. It expanded to 958 ha in July 2001 and 1,700 ha in June 2004, occupying 22.7% of the total area of the park. As called, Tram chim is leaving place of red-headed crane, a symbol of strength, longevity, and fidelity. Giant mimosa firstly attacked to marginal or abandoned fields in the park and after then intensively invaded to crane inhabitation by growing over grass, a crane's food. The infested area was double every year after that. Seeds harbour along the edges of dikes, establish their colony and invade the grass lowland which is submerged seasonally. It also exists under the canopy of melaleuca forest but with low density. The digging of new canal in 2003 across the melaleuca forest to bring water in for checking fire during dry season creates a conducive situation for spreading of *Mimosa pigra*

+ Other places in the Mekong delta

In the Mekong River delta, at locations such as An Giang, Kien Giang, Dong Thap, Long An, and others, mimosa has invaded thousands of hectares. The weed is also threatening to spread into agricultural land in the delta. It is alarming that mimosa will sooner or later spread to agricultural land, especially in the buffer zones of national parks and the flood plains of the Mekong River delta. It has already spread to a big area of agricultural land in Cat Loc district which is in the buffer zone of Nam Cat Tien National Park. Mimosa tends to be more serious in wetland national parks where it is unmanaged. *Mimosa pigra* occurs anywhere in An Giang province, especially with high density in the waste land along the rivers, canals, natural ponds, forest land and invades the cultivated land such as rice fields, gardens. It propagates very fast because it flowers in any season whole year round (Tam, 2008). Along the main canal of Vinh Te from Chau Doc town to Tinh Bien district and in the banks of small canals such as Tha La, Tra Su, Number 10, the weed forms a dense population like a forest. Previously, this area was the place of natural *Sesbania* sp., the plant having plenty of yellow small flowers which are utilised by people nearby as a clean vegetable for their consumption as well as salting to get substantial benefit. The trunks of *Sesbania* sp. were used as fire wood for cooking every day. Farmers now feel losing after the invasion of *Mimosa pigra*. It is difficult to cut because they have many hard and sharp spines which can cause the injury to people who want to destroy them by cutting. Fallowed land during dry season also was invaded by the weed. During the flooding period (September to November) water carrying weed seeds from Cambodia over flows the entire fields in Chau Doc and Tinh Bien. After the flood receding, *Mimosa pigra* germinates and emerges in the entire area (Tam, 2008).

+ South East region

The investigation of the distribution of *Mimosa pigra* on the basin of the Dong Nai river – one of the largest and most economically important rivers of Vietnam – was carried out. A map of *Mimosa pigra* infested areas was established, which covers the Dong Nai river and its main tributaries including the Saigon river, the Be river, the La Nga river and two large water reservoirs: the Tri An and the Dau Tieng. The invasion of *Mimosa pigra* on wetlands of Cat Tien National Park - the largest national park located on the Dong Nai river basin - was assessed in details. The study also found that the transportation of sand excavated from the Dong Nai River and its tributaries for construction purpose is one of the important means of *Mimosa pigra* seed dispersal. The transportation of construction sand can carry large amounts of *Mimosa pigra* seeds to areas far away from the seed source, even beyond the basin boundary. In the tropical South of Vietnam, where flooding occurs annually, mimosa is easily spread and grows quickly. Infestations are thick in wet and flooded areas such as riverbanks, lakes and wetland national parks. Along the banks of the La Nga River the weed infested almost 7,000 ha at a high density of two to eight plants /m<sup>2</sup>. *Mimosa pigra* is taking over Tri An Lake in the southern province of Dong Nai. So far, the plants have invaded around 2,000 hectares of the Tri An Lake area. Each year during the rainy season, flood

waters bring millions of new seeds down the Dong Nai River, and the shrubs proliferate to more areas of the country.

### c) Other places

*Mimosa pigra* has attacked several other provinces and areas nationwide like the coastal, central province of Quang Tri, Bien Lac Lake in the coastal province of Binh Thuan. According to the information from the Department of Agriculture of Lam Dong province, *Mimosa pigra* infested strongly in lowland areas of this province. It invaded seriously about 25 km along the Da Nhim river and dangerously, it invaded about 150 ha nearby of cultivated land of farmers (Phuoc, 2008). *Mimosa pigra* poses a real threat to the people in Kroong, Sa Binh, Ya Ly, Ia Chim, Sa Thay, Dak Ha, Kon Tum town of Dak Lak province. Submerged wet land inside Ya Ly Lake has been occupied by the weed. In Krong, it infests densely in 60 ha of which 50 ha can not be used for crop cultivation. It also invades into perennial crop plantations. It causes the obstacle for the movement of people, animals and usually injures them (Sang, 2008). In the North of Vietnam, this perennial weed is also observed in Ha Tay, Noi Bai, Soc Son (Ha Noi).

## III) Effects of *Mimosa pigra*

### 1) Ecological effects

The presence of mimosa has caused a decline in both the population size and number of species of plants and animals. In Tram Chim National Park its occupation may reduce the density of Poaceae and Cyperaceae plants, such as *Panicum repens*, *Ischaemum rugosum* and *Eleocharis dulcis*, as well as some broadleaf weeds like *Pistia stratiotes*, *Eichhornia crassipes* and *Ludwigia adscendens*. The invasion of mimosa in *Eleocharis dulcis* pasture is threatening the precious bird (*Grus antigone sharpii*), one of 16 species that are highly protected around the World (Triet and Dung 2001). In Nam Cat Tien National Park different bird species often reunite after migration during the flooding season. They use plant material and seeds of various grasses and sedges like *Panicum repens*, *Brachiaria mutica*, *Phragmites karka*, *Ischaemum rugosum*, *Eleocharis dulcis* and *Cyperus* spp as well as broadleaf plants for food. Under dense infestations of mimosa, the populations of these plants have declined sharply causing the disappearance of many bird species. In areas heavily infested by mimosa, few native plants can grow under the mimosa canopy. It was observed, however, that mimosa did not absolutely exclude native plants. Though sporadic, some native plants were found living in dense mimosa stands. Among 45 vascular plant species recorded in 30 sampling plots, 26 species were found in plots which had 70% to 100% cover by mimosa canopy. The loss of native vegetation, especially grasslands, to mimosa invasion negatively affects native animal communities. Grasslands in Tram Chim provide shelter and food sources for several endangered and threatened bird species. The invasion of mimosa is considered one of the direct causes of the reduction of the eastern sarus crane (*Grus antigone sharpii*) population in Tram Chim. *Eleocharis* sedge beds in the core zone of Tram Chim were the main feeding areas of the eastern sarus crane. These areas are now heavily infested by mimosa and abandoned by cranes.

### 2) Economic effects

Farmers living along the La Nga River are concerned about the pollution, due to the mimosa leaf fall to water sources used for drinking and fish feeding. Invasion by mimosa not only obstructs farm practices but also increases the costs of farming due to control. Although farmers in the Mekong River delta have applied physical measures annually to control mimosa, thousands of hectares of alluvial land are now occupied by the weed. In some reserved wet lands such as Tram Chim National Park, *Mimosa*

*pigra* invades and damages the grass and sedge ground to supply food for cranes causing the migration of this bird to other places. This results in losing the attraction to tourists and also being lower down the value of one national reserve area.

#### **IV)Control measures**

##### **1)Prevention**

In response to the invasion, Dong Nai Province has spent thousands of dollars trying several methods to eliminate the plants, but to date, nothing has proven effective. In the past, local administration tried introducing competitive species such as tea trees around Tri An Lake to curb the growth of the invasive plants.

##### **2)Hand weeding**

It was shown from experiments conducted in Nam Cat Tien National Park that pulling could achieve complete control of mimosa. However, it is feasible only with seedlings at an early stage. The cost for pulling depends on the height and age of the plants. Plants younger than two months and less than 100 cm high cost US\$150 /ha to control, while the control of older plants may require more than US\$200 /ha . The pulling method was successfully applied in Nam Cat Tien National Park to control mimosa in some critically important areas liked the Bau Chim (Bird Pond).However, it must be done annually due to the new germination of mimosa from seeds. About 100 ha of cultivated land in Gia Vien village ,Cat Tien district , Lam Dong province were abandoned by heavy occupation by *Mimosa pigra* . In the Natinal Park of Nam Cat Tien, some places inside such as Bau Chim , Bau Ca, Bau Sau have been disturbed by the weed. Every year, the Park spent 3,300 to 6,600 US dollars for controlling them but with little success

##### **3)Physical and mechanical control**

Due to the long flooding season, farmers can cultivate only from April to July in alluvial soil areas along La Nga River. Just after harvesting time, mimosa starts to grow and quickly increases in biomass. To enable sowing of the next crop, farmers have to cut mimosa plants before flooding with a hope to drown regrowth and seedlings. Roots of the first year plants may be inundated and die during the seasonal flooding while roots of older plants can survive. These older plants hinder ploughing during the next season and the weed regrows together with the planted crop. Over several years, mimosa can completely prevent farming. Manual control costs farmers 46 days of labour/ha , equal to US\$100/ ha. During the dry season mimosa re-sprouted seven days after cutting. One or more shoots sprouted from a basal stem and reached 50 cm in height after three weeks. In the case of shallow flooding (less than 30 cm), mimosa plants re-sprouted, but the development of new shoots was less than under no flooding. The cost of labour for cutting depended on the age of plants and level of plant cover. With low density and newly invaded sites, it was around 30 days of labour/ ha. In contrast, in high density areas labour may be up to 60 days/ ha .Farmers' practice and experiments showed that stem cutting followed by flooding only impacted on new plants.

An experiment with four treatments (stem cutting, burning, combination of cutting and burning and combination of cutting and flood) was conducted . Results showed that stem cutting, burning and a combination of these were not effective in controlling mimosa. Mimosa stems re-sprouted quickly after being cut. Two months after treatment, new shoots growing from cut stems reached average heights of 60 to 70 cm and were able to flower and bear fruit. It was difficult to burn fresh mimosa plants, and large amounts of gasoline were used before the fire could be ignited (about two litres of gasoline per square metre). Burns were easier to conduct in areas that had sparse mimosa canopy because there were more grasses on the ground to provide fuel. The experiment showed that fires triggered the germination of mimosa seeds. The number of seedlings in experimental units under the burn treatment were significantly higher than those under other treatments. Therefore, even though not effective in killing mature mimosa plants, fire can be used to facilitate the germination of mimosa soil seed-bank. It was observed in the experiment that young mimosa seedlings were more vulnerable to control treatments such as fire, chemical or manual. The combination of stem cutting and flooding was the most effective control method

among those tested. Cut stems, when submersed in water, were not able to re-sprout. Five months after treatment, when floodwater had receded, it was estimated that about 75% to 90% of treated plants had died. The remaining plants lived and re-sprouted. Most of the cut stems that survived after the flood season were those growing on dikes, where the plants were subject to shorter inundation times. The province is currently relying on manual methods to limit the plant's growth by removing the plant seedlings, digging up their roots, and drying and burning the shrubs to eliminate their seeds. Cutting the mature plants of *Mimosa pigra* to use as fire wood is not the proper way to check the spreading of this weed because their fruits and seeds remain in the soil surface, young seedlings are plenty nearby, their bases have not been uprooted and sprouted easily after cutting .

#### **4)Chemical**

With the exception of paraquat, the herbicides started to kill branches of mimosa 15 or 30 days after treatment ( DAT) . Glyphosate provided the highest efficacy (90.6%at 90 DAT), followed by triclopyr butoxyethyl ester (68.7% at 90 DAT). Metsulfuron methyl killed 44.7% of branches. While glyphosate killed both old and young branches, triclopyr butoxyethyl ester and metsulfuron methyl could kill only young ones. Following the death of branches, all herbicides, except paraquat, started to kill parts of plant including main and basal stems and roots. However, glyphosate killed whole parts of plants at all ages and sizes and gave 89.3% control of mimosa at 90 DAT . Triclopyr butoxyethyl ester and metsulfuron methyl did not kill basal stems of old plants and they controlled only 48.0% and 15.3%, respectively, of mimosa plants. It was concluded that glyphosate, a non-selective herbicide, provided the best control of mimosa. Although herbicides, especially non-selective herbicides, are not encouraged for use in protected areas such as national parks, they are an effective control method when mimosa spreads over a large area and other control methods are difficult to implement. The experiments were done with two non-selective herbicides, paraquat and glyphosate, and two selective chemicals for broadleaf weeds, metsulfuron methyl and triclopyr butoxyethyl ester. All tested herbicides were used at 1.5 times the standard dosage. At that rate, leaf-drop occurred 7–15 days after treatment. Plants treated with paraquat quickly recovered 15 days after treatment while the other herbicides remained active for up to three months. After three months, new regrowth occurred . Metsulfuron was very effective in killing seedlings and young plants but not so effective on mature mimosa.

#### **5)Ecological control**

The control of mimosa invasion will not be successful without the restoration of native vegetation. Revegetation of infested areas is an important step in the mimosa management strategy for Tram Chim. Besides natural revegetation, planting of selected native species may be an effective tool to help restore native vegetation at the early stage of restoration. The results of the study recently suggested several native plant species that may be used for revegetation after the removal of mimosa. On elevated grounds such as earth dikes in and around Tram Chim, the tall grasses *Phragmites vallatoria*, *Saccharum spontaneum* and *Saccharum arundinaceum* are good candidates. On water edges, the legume *Sesbania sesban* would be suitable. *Sesbania* blooms from September to November, and the flower is used by local people as a vegetable. In areas in the buffer zone of Tram Chim, where *Sesbania* was grown in high density by local people for flower harvesting, few mimosa plants occurred. Other research and management of *Mimosa pigra*, 24 species that can be considered for planting along water edges include *Commelina diffusa*, *Hymenachne acutigluma*, *Polygonum tomentosum* and *Coix aquatica* . On grasslands, the following grasses may be planted: *Ischaemum rugosum* and *Paspalum scrobiculatum*. On dry grasslands, *Oryza rufipogon* and on wet grasslands *Eleocharis dulcis* . Other species that may be considered for planting on grasslands include *Eragrostis atrovirens* , *Eleocharis ochrostachy* and *Eleocharis atropurpurea* . Further studies are necessary to find out suitable germination conditions and the capacity of these plants in competition with mimosa. Two examples of success in the ecological control were recorded in Tra Su , one place in Tinh Bien district, An Giang province in the Mekong delta . Recognition the threat from *Mimosa pigra*, the Tra Su Forestry Inspection Station launches a campaign to

control this weed by removing young seedlings, uprooting matured plants and put them under sun drying . Before flood coming, young plants are cut , sprouts emerged and herbicides are sprayed on young shoots . The campaign is kept continuously and resulted in 99% control . After killing the weed , bare soil is planted with eucalyptus . Under the canopy of this forest plants, *Mimosa pigra* can not develop and dies gradually . Seeds under shade also can not germinate . After two years , the weed is controlled and 12 km- bank along Tra Su dike is dominated by eucalyptus plants . This tree also protects the dike from erosion from flood waves . Another story of success was also reported here . A piece of land with the size of 18.4 ha is infested heavily by *Mimosa pigra* . At the beginning of rainy season and before flooding , all weeds are cut down near the soil surface. After weed sprouting , herbicides are sprayed on young shoots . Shoots are susceptible by herbicides and are going to die along with the increment of water depth. The bases of weeds were submerged totally under water . During the process of water receding , melaleuca seedlings with the height of about 1 meter are planted with high density to form a new forest. In such situation, the remained *Mimosa pigra* can not compete with melaleuca . Supplemental hand weeding by uprooting is needed to have pure forest of melaleuca plants . *Mimosa pigra* was control successfully. Controlling *Mimosa pigra* is possible with the continuous and effective measures ( Tam,2008)

### 6)Biological

In a co-research project between NIPP and CSIRO Entomology, funded by the Australian Centre for International Agricultural Research (ACIAR), Vietnam imported two insect biological control agents between 1995 and 1997 for rearing and releasing in the country. They were the mimosa stem borer, *Carmenta mimosa* , and the seed bruchid, *Acanthoscelides quadridentatus* , which had been released and were established in Australia. Both species were subjected to host-specificity tests on different leguminous plants, food plants and fruit trees before releases were approved. They did not affect any of the test plants and *Carmenta mimosa* was released in six locations in the north and four in the south of Vietnam. *Carmenta mimosa* established at the release sites, infected 50–80% of the mimosa stems and spread 2 km after four years. However, *Carmenta mimosa* killed only new shoots and young plants. The insects are now mass-reared and released in combination with other methods such as cutting or pulling. The seed bruchid was released in 1987. It has established but has had no impact on seed production. In 1998, also as part of the ACIAR project, a strain of the fungus, *Phloeospora mimosae-pigrae* , was imported from Australia for evaluation under Vietnamese conditions. The fungus showed a high host-specificity to mimosa and did not attack any of the 25 tested plant species belonging to Mimosaceae, Fabaceae, Gramineae, Cruciferae, Rosaceae, Solanaceae, Amaranthaceae, Compositae, Basellaceae, Convolvulaceae and Rutaceae. The potential of the fungal pathogen to control mimosa was evaluated in a greenhouse with high humidity. Disease incidence (the percentage of the plant diseased) and disease index (the level of infection) increased with higher temperatures . In these tests, plants were inoculated once only in summer, the most favourable period for development of the fungus. Research results indicated that *Phloeospora mimosae-pigrae* fungus and *Carmenta mimosae* insect might be used to control the mimosa plants. In another possibility, farmers find that goat likes to eat the mimosa shoots leading to a recommendation to use the goat for controlling the mimosa. One goat can eat 100-200 plants per day. A study was carried out at An Giang University from April to June 2004 to determine the effects of the foliage of a wild legume bush *Mimosa pigra* on intake and nutrient digestion of growing goats. The experiment used four goats, of 11 kg initial live weight, in a Latin square arrangement of four treatments with 15 day feeding period. In every period one goat was assigned to a different treatment diet. The control diet was composed of *Brachiaria mutica* grass. In the diet MP15, 15% of grass dry matter was replaced by foliage of the legume; in diet MP30, 30% was legume and in diet MP45 it was 45%. Dry matter and total crude protein intake increased with level of mimosa in the diet. Digestibility of all nutrients varied between 68% and 73%.

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