Proceedings of the Eighth International Workshop on Biological Control and Management of *Chromolaena odorata* and other Eupatorieae, Nairobi, Kenya, 1-2 November 2010.
Zachariades C, Strathie LW, Day MD, Muniappan R (eds) ARC-PPRI, Pretoria (2013) pp 134-140

Biocontrol of *Chromolaena odorata* in Timor Leste

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Chromolaena odorata (L.) King and Robinson (Asteraceae) is a major weed in Timor Leste, affecting grazing lands and subsistence farms, reducing productivity and food security. It was the focus of a biocontrol project funded by the Australian Government from 2005-2009. During this period, the gall fly *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) was introduced from Papua New Guinea and Indonesia, where it is widespread. From these initial releases, the gall fly established at seven sites and was subsequently re-distributed to most areas in Timor Leste where chromolaena was a problem. It established at most of the release sites that were revisited and caused a visible reduction in plant density and height. Overall, control of chromolaena by the gall fly in Timor Leste is limited by the severe dry season and the widespread use of fire in clearing lands for agriculture, both of which reduce the ability of gall fly populations to persist at damaging levels. Thus additional agents that can tolerate prolonged dry periods are required to increase the level of control of chromolaena.

KEYWORDS: *Cecidochares connexa*; field monitoring; ectoparasitoid

INTRODUCTION

Chromolaena odorata (L.) King and Robinson (Asteraceae) is a neotropical shrub that is now a major weed in many African and most Asian countries (Zachariades et al. 2009). Chromolaena was first recorded in Timor Leste in the 1980s. It was reported on Flores in eastern Indonesia in 1970 and probably spread to the island of Timor soon after, with the transmigration programme (McFadyen 2004). The weed had originally spread into Indonesia from Burma, down the Malay Peninsula during World War II, probably on military equipment and vehicles (McFadyen 2004).

Vegetation surveys undertaken in Timor Leste prior to 1975 around Viqueque and Baucau recorded several weed species but not chromolaena (Metzner 1977). By 1995, however, there were dense infestations of chromolaena in several places in Timor Leste, such as Hera, Manatutu and Liquica (R. Desmier de Chenon pers. comm. 1995). McFadyen (2004) reported that chromolaena was widespread by 2002, being found west of Dili to Ermera, south to Laklubar and Natar Bora, infesting cropping land, plantation crops, forest clearings, savanna woodlands and pastures.

In Timor Leste, chromolaena forms dense thickets 2-3m high that choke out other vegetation and promote intense dry season fires. Chromolaena also threatens biodiversity by invading areas such as the natural *Eucalyptus*

alba Reinw. ex Blume (Myrtaceae) savannas and open grasslands of the Lautem district in the far eastern part of the island (McFadyen 2004).

Farming systems in Timor Leste consist primarily of small scale swidden (slash and burn) subsistence cropping of rice, maize and coffee plantations, with most farmers also raising small livestock such as goats, sheep, pigs and chickens, and occasionally cattle. Chromolaena can quickly invade areas cleared for farming, outcompeting crops. Maize farmers in particular face an increased burden where chromolaena has completely invaded entire hillsides previously used for maize cropping. Farmers who have relied on common pastures for hundreds of years (da Cruz 2003) are now experiencing increasingly larger infestations of chromolaena within grazing lands, which reduces the carrying capacity of paddocks. In grazing areas, chromolaena has a secondary negative impact on cattle and goat production due to the presence of pyrrolizidine alkaloids that progressively destroy livers, eventually causing death (Biller et al. 1994).

In Timor Leste, control of *C. odorata* by herbicides is technically possible but not economically or environmentally feasible. The large seed bank means that new plants are constantly sprouting, requiring repeated treatments. Herbicide use creates unacceptable negative effects on the savanna grasslands, other vegetation and on ground and surface water. Low literacy levels of farmers may lead to problems with efficient use, safe handling and disposal of herbicides. Manual control is too time-consuming and chromolaena is too widespread for eradication to be considered.

The only sustainable management option is biological control, using insects or pathogens originating from the countries where chromolaena is native. Biocontrol is an established and successful control method for many invasive exotic weeds, especially where the weeds invade land of low economic value such as natural grasslands or threaten biodiversity in natural ecosystems (McFadyen 1998).

In 2005, a biocontrol project for chromolaena commenced in Timor Leste, funded by the Australian Government and following on from similar successful projects in Indonesia and Papua New Guinea (PNG). The gall fly *Cecidochares connexa* (Macquart) (Diptera: Tephritidae) was introduced into Timor Leste from PNG in 2005 and again from Kupang in West Timor (Indonesia) in 2006. This paper reports on the status of the biocontrol project in Timor Leste that concluded in 2009.

MATERIALS AND METHODS

Distribution of *Chromolaena odorata*

To facilitate the release of *C. connexa*, opportunistic and dedicated surveys of the distribution of chromolaena were conducted throughout the country. Previously unreported infestations of chromolaena were recorded and potential release sites were noted. The locations of sites with chromolaena were recorded using a hand-held GPS unit or through web-based sites such as Google Earth or EarthTools.

Field release and establishment of *Cecidochares connexa*

Cecidochares connexa had been released in West Timor as part of another chromolaena biocontrol project about 10 years earlier but had not yet spread to Timor Leste. During field surveys conducted in 2004 to determine the distribution of chromolaena in Timor Leste, *C. connexa* was not found at any site along the border with West Timor. Consequently, *C. connexa* was introduced into Timor Leste from PNG in March 2005, after permission to import, based on host-specificity tests conducted in other countries, was granted by the Minister for Agriculture and the Council of Ministers.

About 1,000 mature galls were collected from the field in PNG and placed in bunches of 200 galls. One bunch was placed in amongst chromolaena at each of three release sites: Maubara (50km west of Dili), Cribas River (south of Manatuto) and Tibar; and two bunches were placed around Baucau Airport, which had the largest chromolaena infestations in Timor

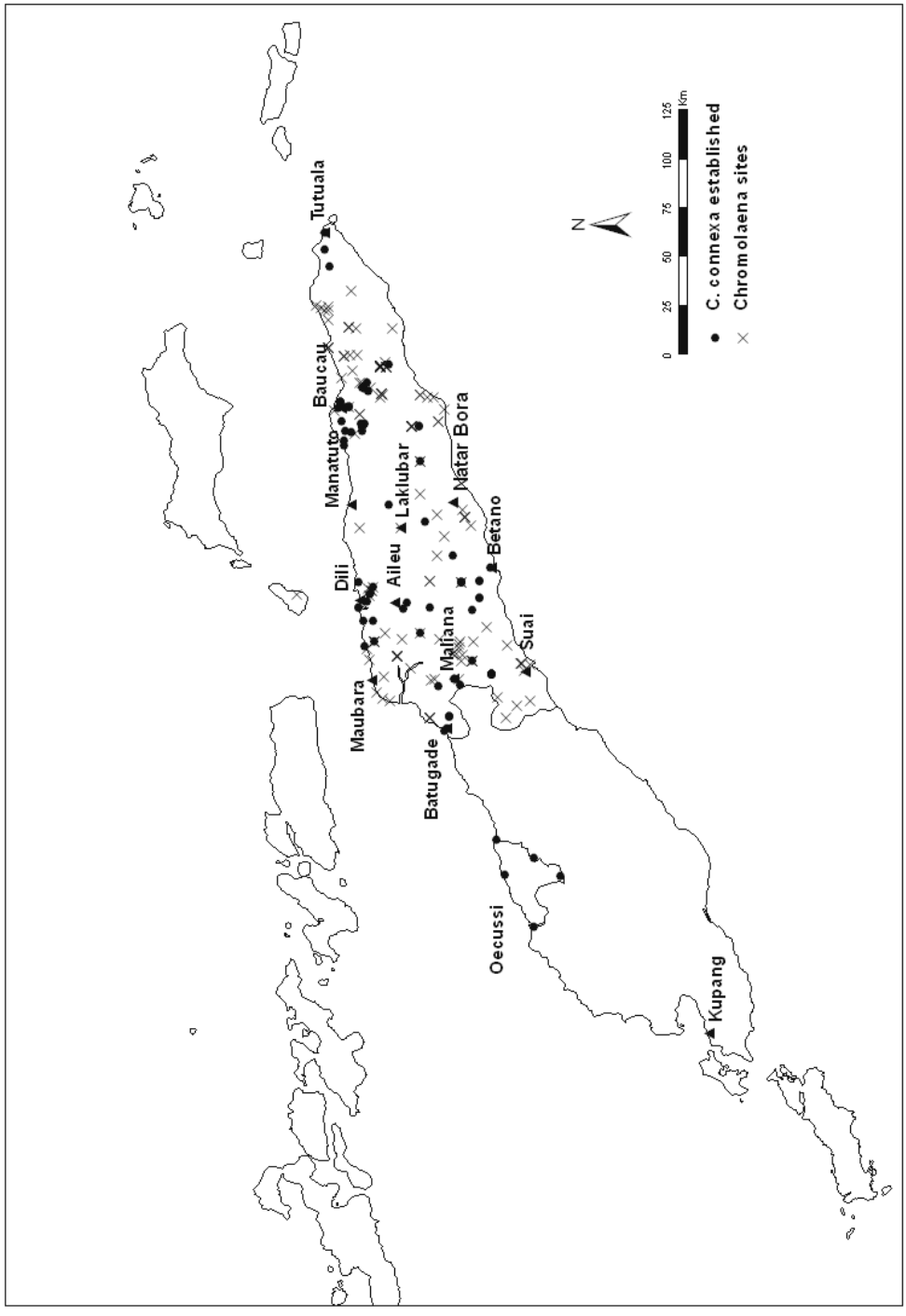

Figure 1. The distribution of *Chromolaena odorata* in Timor Leste (all symbols) and where *Cecidochares connexa* has established.

Leste. The release method was similar to that used in PNG where bunches of stems containing galls are placed in cups of water which are then placed at the base of chromolaena thickets (Orapa and Bofeng 2004).

Additional galls were collected from Kupang, West Timor in March 2006 and released at Hato Udo (70km south of Dili) (500 galls), Betano (on the south coast) (100 galls), Soibada (50km south of Manatuto) (500 galls) and Mehara, near Tutuala at the eastern tip of the island (600 galls). A total of 2,700 galls were introduced into Timor Leste.

Civil unrest from March 2006 severely impacted on the redistribution of the gall fly to other sites. Nursery sites, equipment and records were lost during this period. However, from early 2007 until mid 2008, over 4,000 galls were field-collected opportunistically from where the gall fly had established and re-released at 38 more sites, covering all administrative districts of the country.

The impact of the gall fly on *C. odorata* was assessed at two of the release sites, Tibar and Baucau. The assessments were conducted every six months from the time of the release up until the end of the project in 2009. Measurements of plant density and biomass, stem length and galls per plant were made in $1m^2$ plots selected randomly along a transect.

RESULTS

Distribution of *Chromolaena odorata*

By 2009, chromolaena was found throughout the country at elevations below 1,000m, including the Oekussi enclave bordered by West Timor (Fig. 1), and continues to spread. It is common from Dili to Maliana in the west; around Tibar about 10 km southwest of Dili and Aileu in the hills south of Dili. To the east, chromolaena is found along the north coast road between Manatuto and Baucau, about 120km east of Dili and all the way to Tutuala at the easternmost tip of the island. It is also present south of Manatuto, from Laklubar to Natar Bora on the south coast and west along the south coast to Betano and Suai, near the West Timor border (Fig. 1). However, chromolaena is not present in the very dry region along the north coast between Hera, about 12 km east of Dili, and Manatuto, or the coastal flats between Manatuto and Vemasse, 21 km to the east.

Field release and establishment of *Cecidochares connexa*

Cecidochares connexa established at Tibar and Baucau but failed to establish at the Maubara site which was possibly too exposed and too dry. The Cribas River site was burnt by an extensive wildfire within a few months of the release. A survey a few months after the fire failed to find any galls and the site was abandoned for further releases. However, another survey of the site in 2007 found the gall fly on dense stands of chromolaena regrowth. It is possible that some gall flies may have survived the fire or that the gall fly spread from the Soibada release site.

Overall, the gall fly established at all but three of the 46 release sites. It also naturally spread from where it had established and was subsequently found at Batugade, on the north coast near the Indonesian border, as well as Balibo, inland near the border, and also into the Oekussi enclave. These sites are all about 40km from the closest sites in West Timor at which galls were released 10 years earlier, during a previous chromolaena biocontrol project there. Galls were also seen around Vemasse, about three years after they were released at Baucau, which is 21km to the east of Vemasse. By mid-2009, the gall fly had been released or spread throughout most of Timor Leste (Fig. 1).

At the field-monitoring site at Tibar, there was a noticeable reduction in stem height and density, three years after the gall fly was first released. Much of the data confirming this observation was lost during the civil unrest. However, there were still large stands of chromolaena present in the area in mid-2009. At Baucau in 2009, much of the original widespread infestations contained dead stems, with some regrowth arising from the base of the plants. Almost all of the dead stems contained numerous *C. connexa*

galls, as did much of the regrowth.

DISCUSSION

To date, only *C. connexa* has been released against chromolaena in Timor Leste. While the gall fly is present in most of the chromolaena infestations within Timor Leste, complete control has not yet been achieved. There are several possible explanations. Timor Leste is generally drier than many other countries such as PNG where the gall fly has been very successful (Day and Bofeng 2007) and/or there may not have been enough time for populations to build and have the desired impact on chromolaena. In PNG, control was much slower in the drier provinces of Morobe and Madang than in some of the wet lowland provinces such as New Ireland and East New Britain (Day et al. these proceedings).

In addition, during the dry season in Timor Leste, burning is still common and this may have serious impacts on gall fly populations. Grazing lands in particular are frequently burned to promote 'green pick' for livestock and to 'clean up' the land, consequently killing the gall fly larvae as they aestivate in the galls during the dry season. In areas where chromolaena is burned, there is about a 6-8 month lag before the re-shooting plants are recolonised by the gall fly.

An additional factor that may decrease the effectiveness of the gall fly was the discovery in 2008 of an unidentified hymenopterous larval ectoparasitoid in some galls in both Baucau in the east and Batugade in the west. Parasitism levels were estimated to be around 15%, which is similar to that observed in Indonesia (Soekisman pers. comm.).

In areas where the gall fly has established and is persistent, there has been a noticeable reduction in the density and height of the chromolaena infestations. The gall fly naturally spread to new areas up to 40km away, possibly further, as many sites still need to be checked. Nevertheless, the dispersal rate and distance are comparable to that observed in other countries e.g. PNG (Day and Bofeng 2007) and eastern Indonesia (Wilson and Widayanto 2004). We speculate therefore, that due to the high rate of establishment at many sites and its ease of dispersal, the gall fly may now be present in most parts of Timor Leste.

Despite the successful, wide establishment of the gall fly and the initial impact on chromolaena at several sites, additional biocontrol agents that are adapted to dry conditions and are able to withstand dry season fires are needed. Potential agents to be considered for introduction include: *Conotrachelus reticulatus* Champion (Coleoptera: Curculionidae), a weevil that forms galls on the upper parts of the plant and pupates in the soil and *Dichrorampha odorata* Brown & Zachariades (Lepidoptera: Tortricidae), a small moth which forms galls in the new shoots of chromolaena, has a high rate of increase, short life span and is easy to breed, but may not be adapted to drier climates. *Carmenta chromolaenae* Eichlin (Lepidoptera: Sesiidae), a day-flying moth with larvae that kill the shoot tips but diapauses in the dry season in the stems (which may be a disadvantage) and *Recchia parvula* (Lane) (Coleoptera: Cerambycidae), a highly damaging beetle that is univoltine, slow to establish and requiring great care in rearing (C. Zachariades, pers. comm. 2010) could also be considered.

Time constraints and other factors during the course of this project impeded the ability to import other agents that had been introduced elsewhere. The biocontrol project had to overcome numerous obstacles, not least the civil unrest from 2006-8 that reduced the ability of project staff to travel to release the gall fly and to monitor sites.

There was also initial suspicion and distrust of biocontrol within the community, among farmers, some academics and civil service personnel within Timor Leste, resulting in resistance to the adoption and acceptance of the project. Some people were concerned that the gall fly might attack humans and animals or become a pest and damage their crops. Others were concerned that chromolaena would be eradicated, as it is used as traditional medicine

for humans and animals, and as fertilizer.

An additional obstacle to overcome was the widespread use of fire. Timorese landscapes are highly anthropogenic and shaped by fire. Fire is a traditional farming tool used to clear land in preparation for planting, and there are also cultural beliefs surrounding the use of fire in the landscape. Each dry season, numerous grass fires which are deliberately lit, escape and burn large areas. The greatest risk to the establishment of biocontrol agents is the destruction of release sites by fire in the first few months following a release.

To overcome these obstacles, the project team undertook extensive awareness activities and local communities and farmers were consulted before, during and after introduction and release of the gall fly. Landholders and farmers were engaged as voluntary stewards of the biocontrol agents, where farmers agreed to allow the release of the insects on their land and future access for monitoring, to not burn their land for at least one year, and to prevent fires and protect their areas from wildfire incursions.

Locations for release sites were carefully selected using several key criteria: density of infestation, availability of a water source, risk of fire, and receptiveness of the landholders or farmers to the concept of biocontrol. *Cecidochares connexa* required protection from grazing animals which occasionally feed on chromolaena and from fires for at least the first 12 months after release to allow it to increase to sufficient numbers and spread widely enough to repopulate after a fire event.

Consequently, the gall fly established at most sites at which it was released. The release site at Cribas River experienced a wildfire around June 2005, shortly after the gall fly was released. A survey a few months afterwards found no signs of the gall fly up to at least 200m from the release site. However, a survey in 2007 found the gall fly at the site. It is thought that either the gall fly had dispersed widely prior to the fire due to the density and extensiveness of the chromolaena infestation, and that these outlying populations survived the wildfire and re-populated the burnt site, once the chromolaena plants had recovered, or that the gall fly had dispersed from the release site at Soibada less than 25km away.

Using farmers as stewards proved to be a successful approach to gain trust and acceptance, in the wider community in Timor Leste, of biocontrol as a method of weed management. By 2007, the project team was frequently approached by farmers from areas away from the release sites, requesting that gall flies be released in their districts. Farmers also collected galls for re-distribution to their own farms and villages, with assistance from locals from around the original release sites. Project staff and farmers released the gall fly in almost all areas where chromolaena is a problem in Timor Leste.

There is still a need to check many release sites to determine if the gall fly has established. It is expected that with time the gall fly will continue to spread throughout Timor Leste and offer some control of chromolaena. However, to improve the overall control of chromolaena in Timor Leste, the introduction of new agents that are host specific and have been utilised elsewhere is planned.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr Rachel McFadyen, formerly of the Cooperative Research Centre for Australian Weed Management, for support and advice in initiating the project; Ingu Bofeng, National Agriculture Research Institute, PNG and Ir Wayan Mudita, University of Nusa Cendana, Kupang, Indonesia for supply of and advice on the release of the gall fly; Bert Lukitsch and staff from the Weeds Branch, Dept Natural Resources, Environment, Arts and Sports, Northern Territory Govt, Australia for training in biocontrol in Darwin; and Dr Costas Zachariades, ARC-Plant Protection Research Institute, South Africa for advice on chromolaena biocontrol agents. This project was funded by the Australian Centre for International Agricultural Research.

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