BIOTYPE OF THE INVASIVE PLANT SPECIES *Chromolaena odorata* (ASTERACEAE: EUPATORIAE) IN THE ZAMBOANGA PENINSULA, THE PHILIPPINES

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ABSTRACT

The gross morphology of one of the world's worst invasive plant species, *Chromolaena odorata*, now widespread in three provinces of the Zamboanga Peninsula, was examined and compared to the characteristics of Asian/West African (AWA), Southern African (SA), and Central and South American biotypes. *C. odorata* from the three provinces of Zamboanga Peninsula is very similar with the AWA and the Central and South American biotypes. Implications of this finding are discussed in the light of the species' invasion and biocontrol in South Asia, Southeast Asia and the Philippines.

KEYWORDS: *Chromolaena odorata, biotype, Asian-West African biotype, Southern African biotype, Central and South American biotype, gross morphology, invasive plants*

INTRODUCTION

Although originally used in entomology, the term biotype has been generally applied to individuals of a population with similar genotypes and indistinguishable morphology but differ in expressed biological attributes (Shufran and Payton 2009). For example, insect biotypes are individuals that cause damage to a crop plant that is resistant to other individuals of the same insect species (Maxwell and Jennings 1980). However, the usefulness of the biotype concept in systematics and evolution of species is recently debated (*e.g.* Downie 2010). The plant species *Chromolaena odorata* (L.) R. M. King and H. Robinson has two recognized biotypes as it became highly invasive and allelopathic after its introduction to Asia and West and South Africa due to the absence of its natural enemies, e.g. the lepidopteran *Pareuchaetes pseudoinsulata* (Muniappan and Bamba, 2000; Robertson et al. 2008; Zacchariades et al. 2009). These Asia and West Africa (AWA) and Southern

Africa (SA) *C. odorata* biotypes show differences in morphology, physiology, reproduction, and ecology despite low levels of genetic variation (high similarity) within each form (Kluge, 1990; Lanaud et al., 1991; Scott et al., 1998; von Senger et al., 2002; Ye et al., 2004). The AWA biotype invades areas in the Afro-Eurasian region with a minimum annual rainfall of 1200 mm (McFadyen, 1989). The SA biotype, on the other hand, is more cool tolerant (Kriticos et al., 2005), occurring in frost-free zones with an annual rainfall of 500–1500 mm (Goodall and Erasmus, 1996). Much of the global spread of *C. odorata* could be linked to the extensive movements of people, machinery and plant materials rather than by wind (Holm et al., 1977; McFadyen, 2002).

Chromolaena odorata is a member of the Eupatorieae, within the subfamily Asteroideae (King and Robinson, 1970; APG II, 2003) in the family Asteraceae, formerly called Compositae (Toelken, 1983). It was formerly known as *Eupatorium odoratum* L. (King and Robinson, 1987). *Chromolaena* includes more than 165 species, all native of South Florida of USA, South and Central America, and the West Indies (King and Robinson, 1987; Gautier, 1992), but only *C. odorata* has become notoriously invasive outside its native range (McFadyen 2002).

Chromolaena odorata is common in areas with open, freely-drained grounds but is absent in natural forests (McFadyen, 1991). The invasive *C. odorata* grows rapidly, and often forms dense scrambling thickets overgrowing natural vegetation and subsistence and commercial crops, grazing lands, and silviculture (Prasad et al., 1996; Zachariades et al., 2009). It can suppress other plants by competing for light, nutrients and water, and by allelopathy (Orapa, 2004). It flowers once a year producing massive amounts (93,000 to 1,600,000) of viable seeds per plant (Blackmore, 1998). Peaking in December–January in the northern hemisphere and June–July in the southern hemisphere, flowering is initiated by a decrease in both day length and rainfall (Sajise et al., 1974; Gautier, 1993).

In the Philippines, *C. odorata* has different local names: *daladay* (Balabac), *talpus palad* (Tagbanua); *hulohagonoy* (Negros); *gonoi* (Palawan), *lahuneri* (Marinduque); *hintatakao* (Visayas); *bungarngar* (Mindoro) and *hagonoy* in other parts of the country (Aterrado and Talatala-Sanico, 1988). *C. odorata* was first introduced in Zamboanga during the 1960s through traders from Borneo, then shortly thereafter in Palawan and Mindoro (Pancho and Plucknett, 1971). From there, it spread very rapidly northward to Luzon and extensively in Mindanao and the Visayan islands and in areas surrounding Manila (Pancho and Plucknett, 1971). All soil types in the Zamboanga Peninsula appear to be suitable for growth of *C. odorata* as this invasive plant is found to be distributed abundantly in the region (Codilla and Metillo, 2011). However, it has already been about 52 years since it was first reported in the country, and yet published literature about the species in the Philippines does not indicate if it is an AWA or SA biotype. It is very important to establish the identity of *C. odorata* populations in order to better prepare for its impact on the local terrestrial

biodiversity and to implement integrated and sustained control measures (Raimundo et al., 2007). Because alien biotypes differ in aggressiveness between locations (Scott et al., 1998; McFadyen, 2002), knowledge on biotype identity is an important step in understanding its biology and ecology and its response to environmental changes such as El Niño events and climate change on a larger scale (Kriticos et al., 2005). There is also a need to highlight the *C. odorata* biotype in order to increase awareness among stakeholders including farmers and government agencies about this invasive non-native plant species.

This study was conducted in order to determine the morphological characteristics of *C. odorata* species invading three provinces of the Zamboanga Peninsula, and to assess if such species are morphologically similar to Asian-West African (AWA) or Southern African (SA) biotypes.

MATERIALS AND METHODS

Specimens were collected during a survey of the three provinces of the Zamboanga Peninsula. Gross morphological examination of *C. odorata* was done using a hand-lens and digital camera (Sony 12.1 mega pixels, model HD movie 720p). One sample of entire *C. odorata* plant was randomly selected from each of the 75 sampling sites assigned randomly in 25 municipalities of the Zamboanga Peninsula (27 from Zamboanga del Sur, 21 from Zamboanga Sibugay and 27 from Zamboanga del Norte (Figure 1). Each sample and their different plant parts (i.e., young and mature leaves, young and mature stems, flowers, branches, and roots) were photographed. Characteristics were then compared to those in the AWA and SA biotypes as described by von Senger et al. (2002), Kriticos et al. (2005), Joshi (2006), Wilson (2006), and Zachariades et al. (2009).

RESULTS AND DISCUSSION

Figure 2 shows the morphological characteristics of the Zamboanga Peninsula *C. odorata* specimens. Mature specimens are 1.5-2.0 m in height but very tall individuals could reach a maximum of 6 m as reported from the Pacific Islands (PIER, 2001). The mature leaves are green but are purple when young. The texture of both the ventral and dorsal parts of the leaves is rough due to the presence of trichomes. Its stems are green when young but become brown when old, and have trichomes profusely distributed all over. The branches are lax and opposite to each other. Its flowers are pale-lilac in color with pointed bracts. The roots of the large plants have underground corms. The different features of plant parts are all similar, suggesting that *C. odorata* in the three provinces of the Zamboanga Peninsula are of only one kind from the standpoint of external morphology.

Table 1 shows distinguishing characteristics of *C. odorata* plants in the Zamboanga Peninsula, the AWA and SA biotypes, and those in South and Central America. The leaves of *C. odorata* from the Zamboanga Peninsula have trichomes on both surfaces, dark green (except for young ones which are purple), ovate and have prominent ribs. These characteristics are also seen in AWA biotypes, but clearly differ from the full-grown leaves of SA biotypes which are smooth, yellow-green when growing under full sun, and dark green when growing in semi-shaded areas, with young leaves often red and smaller especially when growing under full sun. The stems of *C. odorata* plants from the Zamboanga Peninsula have trichomes, green when young turning brown when mature, similar with stem characteristics of AWA biotypes but different from the stem features of SA biotypes which are smooth and yellow-green. The flowers of the Zamboanga Peninsula specimens are pale-lilac in color with bracts which have sharp tips, again very similar with the floral characteristic of AWA biotypes. In contrast, the flowers of SA biotypes are white, narrower, bracts have rounded tips which tight around the flower-head. The large corms of *C. odorata* plants from the Zamboanga Peninsula are similar to those found in AWA biotypes. SA biotypes have less prominent corms. The branching of biotypes in the Zamboanga Peninsula is similar to AWA biotypes with branching that are more lax as against the more upright branching in SA biotypes. These results show that the morphological characteristics of *C. odorata* found in Zamboanga Peninsula are more similar with Asian/West Africa (AWA) and South and Central American biotypes than those found in Southern Africa (SA).

This study, therefore, establishes the fact that *C. odorata* in the Zamboanga Peninsula is more related to the Asian-West African (AWA) biotype than that of the Southern African (SA) biotype based on gross morphological grounds. The Asian biotype was introduced by the West Indies British troops in 1845 as an ornamental plant in Calcutta, India (McFadyen and Skarrat, 1996). By early twentieth century, it was widespread in western tropical India, Sri Lanka, Bangladesh, Nepal and Myanmar (Burma) (Rao, 1920). The species became established in Malaysia as early as 1914 (Azmi, 2002). During World War II, the spread to the east progressed into southern China, then in Thailand, Vietnam and Laos in the 1930s (Gautier, 1992; Roder et al., 1995), and then southwards to Sumatra by 1934, the Philippines and Guam in the 1960s (Stone, 1966; Pancho and Plucknett, 1971; Henty and Pritchard, 1973; Peng and Yang, 1998; McFadyen, 2002), Timor and Taiwan in the 1980s (Wu et al., 2004; Lai et al., 2006), Northern Australia in early 1990s (Waterhouse, 1994), and eastern Indonesia, Papua New Guinea and most of the Micronesian islands by 2000 (McFadyen, 2002; Muniappan et al., 2004). The invasion in Papua New Guinea marked the spread to the South Pacific Islands (McFadyen, 2002). By early 2000, *C. odorata* in Asia is close to reaching saturation as it has invaded nearly all countries between the Tropic of Cancer and Tropic of Capricorn (Raimundo et al., 2007).

A study on biotypes is justified because it is likely that the Southeast Asian biotype is a combination of invasions from India and South America. Tjitrosoedirdjo (2005) stressed that *C. odorata* in Indonesia mainly comes from neotropical America, but may have also been from Asia and Africa as reintroductions. Muniappan et al. (2005) also believed that the rapid spread in Asia is due to multiple introductions, *e.g.*, the entry into Southeast Asia could be through Singapore via ballast ships from the West Indies as early as 1934.

The West African variety originated from Asia and was first reported in 1934 in Nigeria; the rest of the invasion proceeded to Central Africa and then East Africa (Muniappan et al., 2005). The South African (SA) biotype is very different from the Asian-West African biotype. Originally sourced from northern Carribean, the SA plants became part of the Cape Town Botanical Gardens collection in 1858 (Zachariades et al., 2004), and spread throughout South Africa including Natal and Durban by 1947 (Muniappan et al., 2005).

According to Pancho and Plucknett (1971), the spread of *C. odorata* to Mindanao in 1960 was via ships trading between Borneo and the southwestern islands of the Sulu Archipelago. The invasion in the Zamboanga Peninsula then became inevitable. The spread to Palawan islands, then to Luzon and Mindoro is believed to have originated also from Northern Borneo (McFadyen and Skarrat, 1996). A hypothetical invasion map is shown in Figure 3. In 1996, *C. odorata* has already invaded the entire country at a scale much worse than the spread of *cogon* or *Imperata cylindrica* (McFadyen, 1996).

The lack of information on the true identity of local biotype of invasive species results in the failure of control and management measures and the continued expansion of *C. odorata*. For instance, North Queensland populations are difficult to contain because of asynchronous flowering in different locations (McFadyen and Skarrat, 1996). SA biotypes are more susceptible to fire but are more cool tolerant (Kriticos et al., 2005) while the AWA biotypes are more fire resistant, resprouting from crown (Zachariades et al., 2004, 2009). Local Zamboanga Peninsula populations are very fire resistant that farmers would rather uproot entire plants because shoot regrowth is quite fast after burning. The use of potential biological control insects would require host-specificity and effectiveness trials because *C. odorata* biotype differences would render insect species effective in one country but less effective in others (Zachariades et al., 2009). For example, eradication of *C. odorata* using the gall fly *Cecidochares connexa* from Indonesia was attempted in Southern Mindanao in mid 1990s but the die back rate was achieved only at a rate of 59% (Aterrado and Bachiler, 2002), unlike in North Sumatra where the insect is most successful (McFadyen, 2002). The widely used control insect species now are only effective in *C. odorata* defoliation but not on the subterranean corm or root system which is an effective part of the plant in its spread (Roder et al., 1995; Te Beest et al., 2009). Li et al. (2002) noted a redirection of biomass resource allocation to reproduction and growth in branches and stems after leaf herbivory. Furthermore, different populations of AWA biotypes differ in allelochemical

properties. Recently, Codilla and Metillo (2012) observed the presence of mainly alkaloids and steroids from leaves of Zamboanga samples. In contrast, leaves of West African (Biller et al., 1994) and Thailand (Pisutthanan et al., 2006) biotypes contain more flavonoids, while those from India (Suriyavathana et al., 2012) contain all of these phytochemicals. These differences in phytochemical properties could help explain the persistence of *C. odorata* in Zamboanga Peninsula because alkaloids and steroids in their leaves may have altered the reproduction among biocontrol insects used. McFadyen (2002) noted that these insects are present in southern Mindanao, but scarce in the midst of abundant *C. odorata*. It has been 52 years since *C. odorata* was first recorded in the Peninsula, and by now, we speculate it has become naturalized and possibly developed an invasive weed niche reflective of its microhabitats, and possesses subtle physiological, morphological, and ecological differences from conspecifics inhabiting other Southeast and South Asian countries.

CONCLUSION AND RECOMMENDATION

This study was conducted in order to establish the morphological characteristics of *C. odorata* species invading the three provinces of Zamboanga Peninsula, Philippines; and to determine if such species are similar to Asian-West African (AWA) or Southern African (SA) biotypes. The *C. odorata* plants invading the three provinces of Zamboanga del Sur, Zamboanga del Norte and Zamboanga Sibugay are of the same phenotypic kind belonging to the AWA biotype. Since the sole basis of determining the biotype of *C. odorata* species in the study area is mainly by gross morphological examination, determination of the genetic composition of plants is recommended.

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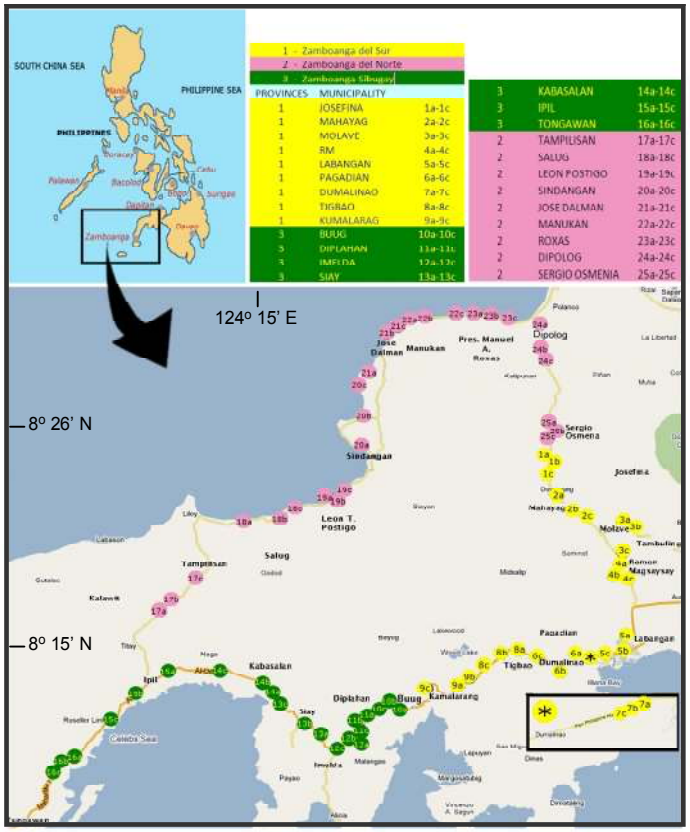

Figure 1. Map of the three provinces of Zamboanga Peninsula showing the sampling locations.

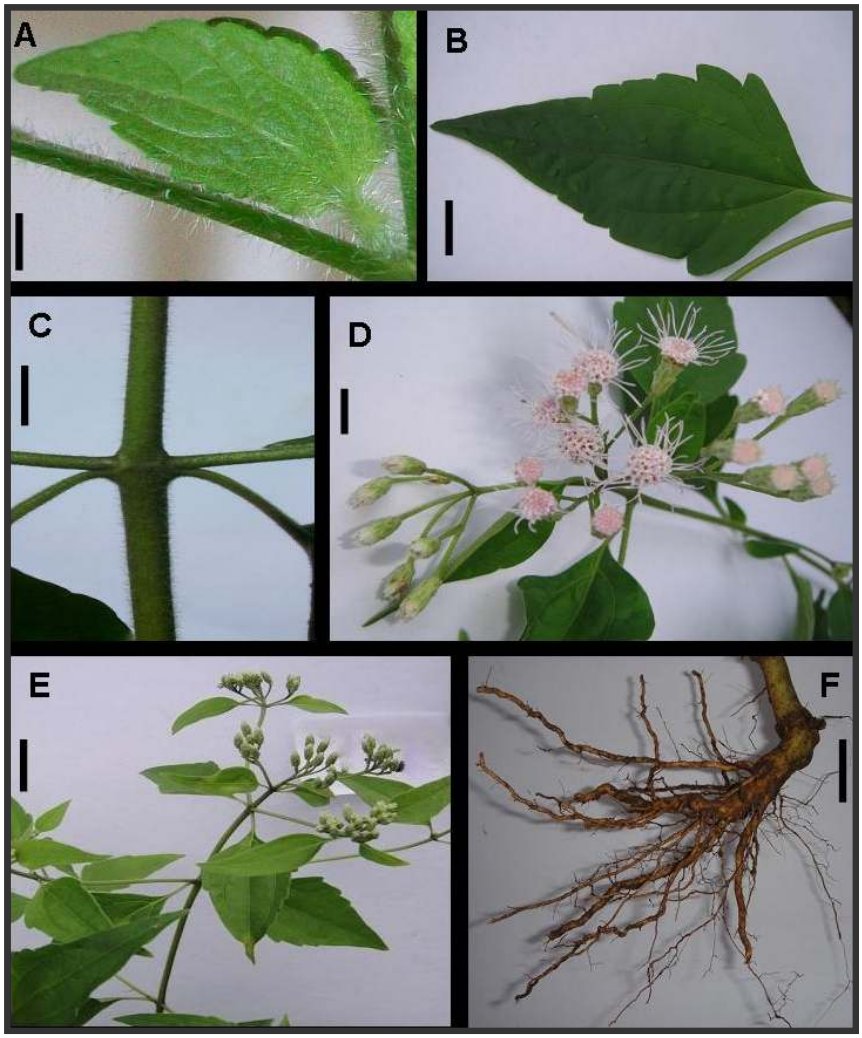

Figure 2. Plant parts of *C. odorata* from the Zamboanga Peninsula. A. young leaf with trichomes, B. mature leaf, C. mature stem with a shade of light brown (entirely green when young) and trichomes, D. pale lilac flowers on stem, E. lax lateral branches that develop in pairs, F. fibrous roots with corm. Bars (A, B, D = 1 cm; C = 0.5 cm; E, F = 2.5 cm).

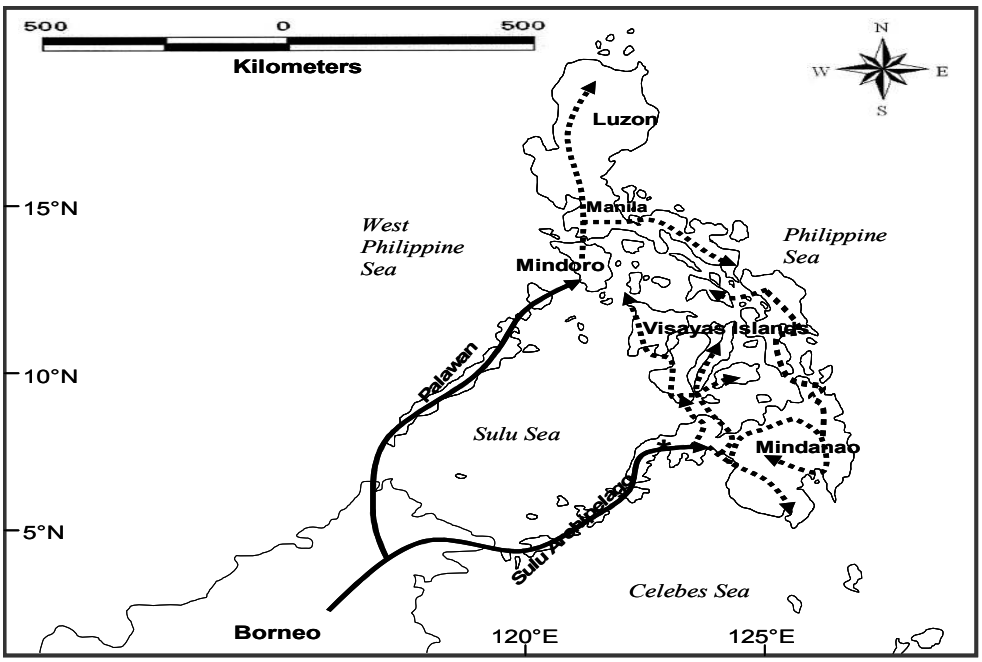

Figure 3. Map of the Philippines showing the spread of *C. odorata* (solid arrows) from Borneo to the Sulu Archipelago and the Zamboanga Peninsula (*) and to Palawan and Mindoro Island (Pancho and Plucknett 1971). The hypothetical spread of *C. odorata* to other parts of the country is shown by broken arrows.

Table 1. Descriptions of plant parts of *Chromoloaena odorata* from the Zamboanga Peninsula, Asia and West Africa, Southern Africa and South and Central America.

Plant Part	Zamboanga Peninsula	Asia and West Africa (AWA)	Southern Africa (SA)	South and Central America
Leaves	- with trichomes on both surfaces - dark green in color - young leaves have purple color - large leaves with prominent ribs (this study)	- with trichomes giving a rough texture, particularly to younger leaves - grey-green to dark green - young leaves often purple, especially when growing in sun	- smooth, generally smaller - yellow-green when growing in sun, dark green in semi-shade - young leaves often red, especially when	- dark green, prominently-ribbed and pilosulose on both surfaces (Vanderwoude et al., 2005)

		- leaves often larger, more prominently ribbed (Wilson, 2006)	growing in sun (von Senger et al., 2002)	
Stem	- stems with trichomes - green in color (young) and brown base stems (this study)	- stems hairy - grey-green to dark green (Wilson, 2006)	- smooth and yellow - green in color (von Senger et al., 2002)	- green and densely pilosulose (Vanderwoude et al., 2005)
Flower	- pale lilac in color - bracts with sharp tips (this study)	- pale lilac in color - broader individual flowers - bracts with sharp tips, lax around flower-head (Wilson, 2006)	- white in color - narrower individual flowers bracts with rounded tips, tight around flower-head (von Senger et al., 2002)	- pale lilac and ovate bracts (Vanderwoude et al., 2005)
root system	- larger plants have underground corm structures (this study)	- larger plants have underground corm structure (Joshi et al., 2006)	- corm less prominent (von Senger et al., 2002)	- corm prominent (Vanderwoude et al., 2005)
branching	- more lax as these are not following an uptight growth form more adapted to tropical conditions (this study)	- more lax - resprouting from crown - resistant to fire - more adapted to tropical conditions (Wilson, 2006)	- more upright growth form, especially young growth in dense - more susceptible to fire (von Senger et al., 2002)	- sprawling (Vanderwoude et al., 2005)