**INTRODUCTION**

Cameroon is located from 1° to 14°N and 8° to 16°E, bordering Nigeria, Chad, Central African Republic, Congo, Gabon and Equatorial Guinea. In Cameroon, *Chromolaena odorata* (L.) King & Robinson reaches 3m height, flowering at the beginning of the dry season in December. It invades forest gaps, cropped fields, cleared forest land and fallows, open grasslands and savannahs. Susceptible to shade, it becomes less prominent and disappears as fallows age, being outcompeted by understorey Marantaceae and Zingiberaceae and pioneer tree species. However, where these species are absent, *C. odorata* may persist.

**COMPETITION WITH MORE NOXIOUS WEEDS**

*Imperata cylindrica* L. Rauesch is a pantropical grass of the tribe Andropogoneae, subtribe Saccharine. It infests nearly 500 million acres of plantation and agricultural land worldwide. In West Africa, it is common in the moist savannah belt between Senegal and Cameroon. Its origin is disputed and subspecies may be native to West and Central Africa or may originate elsewhere (den Breeyen, pers. comm.). *Imperata cylindrica* is difficult to manage as a fallow, dieback in the dry season creates a fire risk, and its sucrose-rich rhizomes attract rodents that eat crop seeds and destroy seedlings. In western Cameroon, where some of the largest expanses of *I. cylindrica* in the country are present, the local name in Mbo-o language is “mbuen” meaning something cruel that sterilises the soil. *Imperata cylindrica* land is avoided by farmers (Yonghachea, 2005).

Farmers in Côte d’Ivoire reported that *C. odorata* helps to prevent the establishment of *I. cylindrica* (de Rouw, 1991). To assess competition with *C. odorata*, we planted *I. cylindrica* rhizomes in pots containing soils collected from savannah, *C. odorata* invaded savannah and forest in Central Cameroon, and measured growth of *I. cylindrica* rhizomes and the relations of the grass with seedbank dynamics. We harvested emergent communities after six months, counting and weighing individual plants. *Imperata cylindrica* biomass production per pot was significantly affected by soil origin with the lowest *imperata* biomass produced in the *C. odorata*-invaded soils. When *C. odorata* mass was added as a covariate in this model, it was significant (P < 0.05) and was negatively correlated with the biomass of *I. cylindrica*, hence growth of imperata was reduced by the presence of *C. odorata* (Norgrove, 2007).

**EFFECTS ON PLANT COMMUNITIES**

In the North West province of Cameroon, we looked at the impact of *C. odorata* invasion on plant community composition in six paired invaded and non-invaded savannah sites. We found no effect of invasion on mean species number, yet community composition was affected. There was a loss of monocotyledonous species, including *Aframomum* spp. and *Murdannia simplex*, and accompanying co-invasion by some dicotyledonous alien weed species, notably *Oldenlandia* sp., *Stachytarpheta cayennensis* and *Ageratum conyzoides*. Areas invaded with *C. odorata* had twice the plant biomass (9.44Mg ha⁻¹) of non-invaded areas (4.52Mg ha⁻¹). Furthermore, *C. odorata* addition to savannah systems...
increased litter N and K inputs. *C. odorata* leaves contained 40mg g⁻¹ of N and 23mg g⁻¹ of K, compared with 6-10mg g⁻¹ N and 11-17mg g⁻¹ K for grasses (Yonghachea, 2005).

**SOIL FERTILITY CHANGES?**

Farmers in Cameroon have reported that they associate *C. odorata* presence with higher soil fertility (Yonghachea, 2005). Likewise, in Ghana, farmers consider both *C. odorata* and earthworm casts as indicating good soils and link these mechanistically by stating that *C. odorata* provides litter input, shade, and a moist environment which promotes earthworm activity (Adjei-Nsiah *et al*., 2004). In southern Cameroon, Norgrove and Hauser (1999) found that weed biomass, dominated by *C. odorata*, explained 76% of variation in earthworm cast production in a cropped field. Subsequently, in an adjacent site, Norgrove *et al*., (2003) found that mulching with *C. odorata* resulted in an increase in cast production and that these casts were richer in nitrogen and potassium than those derived from non-mulched plots, probably due to feeding on the N- and K-rich *C. odorata* residue. To verify these observations, we measured soil biological, physical, and biochemical parameters in different land uses systems in replicated trials in central and northwest Cameroon.

Soil compaction was assessed by bulk density and a static hand penetrometer. Topsoil (0-5cm) bulk density was lower (p < 0.01) in *C. odorata*-invaded areas (0.87Mg m⁻³) than in savannah (1.04Mg m⁻³). Soil resistance was lower (P = 0.02) under *C. odorata* (1742kPa) than under savannah (3239kPa). Morning, midday and evening topsoil temperatures were always lower (P < 0.0001) under *C. odorata* (24.1; 25.3; 26.8°C) than under savannah (27.1; 29.4; 28.5°C) (Tueche and Norgrove, unpubl.).

In the same sites, we also evaluated earthworm species richness (Norgrove *et al*., 2008). We found that earthworm species richness was higher in *C. odorata* invaded savannah than in non-invaded savannah and there was a significant increase in the earthworm density. Two pantropical species, *Dichogaster annae* and *Nematogenia panamaensis*, were found exclusively in *C. odorata*-invaded sites (Norgrove *et al*., 2008). Similarly, in land-use assessments in southern Cameroon, these species were found only in *C. odorata* fallow (Birang *et al*., 2003). Such widespread species may be better adapted to high nutrient environments such as that under a *C. odorata* canopy and such conditions may also permit increases in the population densities of native Eudrilidae.

Beta (β)-glucosidase is the final enzyme of the cellulase system which hydrolyses cellulose to glucose. Cellulose comprises 40-70% of total litter mass and its decomposition and mineralization rates may be limiting factors within the soil carbon cycle. We found that β-glucosidase activity was twice as high in *C. odorata*-invaded savannah than in uninvaded sites of similar soil chemistry (10 compared with 20ug g⁻¹ soil h⁻¹). Furthermore, activity could be promoted by the addition of *C. odorata* residue whereas comparable amounts of grass residues did not increase activity (Dux, 2005).

**DIFFERENT LIVELIHOODS, DIFFERENT PERCEPTIONS**

In North West province, the dominant Aghem people use a shifting cultivation system whereby land is cultivated for four years and then abandoned for at least five years. In the first year of cultivation, referred to as “sìfuwó” (new farm), soil mounds called “ekang” are made, filled with vegetation and burned. Maize (Zea mays), cocoyams (*Xanthosoma sagittifolium*), sweet potatoes (*Ipomoea batatas*), cassava (*Manihot esculenta*) and beans (*Phaseolus vulgaris*) are planted. In the second year called “udung”, the mounds are rearranged into ridges and maize, cocoyams and cassava are cultivated. In the third year, known as “kibvo”, only groundnuts (*Arachis hypogaea*) and maize are planted. By the fourth year of cultivation, “tii”, maize and cowpeas (*Vigna unguiculata*) are grown and then the field is abandoned. If the fallow is dominated by *I. cylindrica* rather than *C. odorata*, the land is only cropped with *Vigna subterranea* (bambara groundnut) in year 1, groundnut in year 2 and cowpea in year 3 before fallowing.

The farming Aghem people consider *C. odorata* as the “least–worst” option for fallows. In these fields they grow a greater diversity of crops (Yonghachea, 2005). The use of a biological control agent for *C. odorata* in this zone would result in greater infestation of *I. cylindrica* and greater weeding drudgery. However, for their pastoralist transhumant neighbours, the Fulbe, relying on grazing savannah land, *C. odorata* negatively affects their livelihood strategy.

**CONCLUSIONS**

In conclusion, in the context of land users in Cameroon, *C. odorata* invasion in savannahs may have had both negative and positive effects. *Chromolaena odorata*-invaded areas are associated with higher topsoil N status, higher soil faunal densities and activities. This is an association, so cause and effect cannot be distinguished, yet there are plausible mechanistic models to offer an explanation. *Chromolaena odorata* maintains a canopy during the dry season so is less flammable (Norgrove, pers. obs) and prone to wild fires so N volatisation in these areas is reduced. Therefore, N and C are retained and returned to the soil through litterfall and decomposition. Consequently, soils may have higher soil faunal and soil enzyme activity.

In these savannahs, *C. odorata* does cause species shifts with an increase in alien weeds and/or unpalatable species. Thus savannahs are rendered less useful for grazing and this negatively affects pastoralists’ livelihoods. However, for farmers, a reduction in *C. odorata* abundance through biological control or other mechanisms may result in a more problematic weed community dominated by *I. cylindrica*, so management options should be considered within cultural context.

**REFERENCES**


Introduction

Chromolaena odorata (L.) King and Robinson was first reported in Nigeria in 1937, probably introduced through the importation of contaminated Gmelina arborea Roxb. seeds to Nigeria from Sri Lanka (Ivens, 1974). Chromolaena odorata is now widespread in the southern parts of Nigeria, being present in more than 20 of the 36 states. The weed dominates by colonizing the forest margins, rangelands, plantations and arable crop farms.

Chromolaena odorata is known to harbour some important pests of crops, notably Zonocerus variegatus (L.) (Orthoptera: Pyrgomorphidae) and Aphis spiraecola (Patch) (Homoptera: Aphididae) (Oigiangbe et al., 2007). A non-nutritional relationship between C. odorata and Z. variegatus causes increased populations and pestilence of the grasshopper in West Africa (Boppré, 1991). Aphis spiraecola is thought to be East Asian in origin but is now widely distributed across several continents. Kranz et al. (1977) reported the aphid on over 65 plant genera, including economically important crops like citrus, cacao, papaya, annona and some vegetables. It is the main aphid pest of citrus worldwide (Pfeiffer et al., 1989). The use of C. odorata by A. spiraecola poses the concern of a possible pest outbreak in citrus plantations and garden eggplant farms in Nigeria. An understanding of the relationship between C. odorata and A. spiraecola as well as the population dynamics of the aphid in C. odorata-infested areas is vital to the success of any control effort against the aphid. This paper attempts to provide such information from Nigeria and we expect that this study will add to the existing information on the menacing effects of C. odorata in the tropics.

Materials and Methods

The study was carried out at the Nigerian Institute for Oil Palm Research (NIFOR), Benin, Nigeria between August 2004 and January 2005. The study area has a bimodal rainfall pattern with annual precipitation of over 1600mm and a mean annual temperature of 26.7°C.

Four 100 m line transects, running in different directions and haphazardly laid out in a C. odorata-infested field, were sampled weekly for the presence of A. spiraecola, using the systematic and stratified sampling method described by Hammond (1992). Four quadrats of 1 m² each, the positions of which were randomly selected along each of the 100 m transects, were sampled for collection of data. Sampling was conducted weekly between 07h00 and 10h00 from August 2004 to January 2005. The number of C. odorata plants within each 1 m² quadart was counted and each plant was thoroughly examined for aphids. Within each quadart, the number of aphid-infested and non-infested C. odorata plants as well as the number of aphids per plant were counted. It was observed that aphid-infested C. odorata developed mottled leaves (abnormal leaf formation), so the number of mottled C. odorata leaves per plant was also counted weekly. The ant Crematogaster africana Mayr (Hymenoptera: Formicidae) was always found associated with the aphid. Data were collected on mottled leaf numbers and C. africana for three months (late October 2004 to mid-January 2005) to investigate the ant-aphid relationship. A linear regression was fitted to data to determine relationships between A. spiraecola population, climatic parameters, damage to the plants and ant numbers. A t-test was conducted to determine levels of significance (Genstat statistical software version 9.0).

Table 1. Mean density (± S.E.) of Chromolaena odorata plants and Aphis spiraecola along transects over a 6-month sampling period (n = 64 quadrats sampled per month). Mean monthly temperatures and RH are indicated.

<table>
<thead>
<tr>
<th>Month</th>
<th>No. chromolaena plants m²</th>
<th>No. Aphis spiraecola m²</th>
<th>Mean temperature (°C)</th>
<th>Mean Relative Humidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 2004</td>
<td>7.5 ± 0.2</td>
<td>445.2 ± 14.5</td>
<td>25.3</td>
<td>90</td>
</tr>
<tr>
<td>September</td>
<td>4.0 ± 0.1</td>
<td>220.6 ± 27.2</td>
<td>26.8</td>
<td>88</td>
</tr>
<tr>
<td>October</td>
<td>3.5 ± 0.1</td>
<td>218.0 ± 24.5</td>
<td>27.1</td>
<td>86</td>
</tr>
<tr>
<td>November</td>
<td>3.6 ± 0.2</td>
<td>150.5 ± 23.4</td>
<td>28.4</td>
<td>81</td>
</tr>
<tr>
<td>December</td>
<td>3.2 ± 0.1</td>
<td>116.6 ± 6.0</td>
<td>29.2</td>
<td>81</td>
</tr>
<tr>
<td>January 2005</td>
<td>3.5 ± 0.2</td>
<td>105.0 ± 2.8</td>
<td>29.8</td>
<td>79</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

Occurrence of *Aphis spiraecola*

Over the sampling period, a mean of 4.22 *Citrus clementina* plants and 209 *A. spiraecola* per m² were present in the quadrats sampled (Table 1). Hermoso de Mendoza et al. (2006) reported the Economic Threshold and Economic Injury Level of this aphid on *Citrus clementina* to be 322 and 370 per m² respectively, while Hall et al. (1972) reported that the number of this aphid per *C. odorata* plant varied greatly, from 16 in low infestations to over 150 during a severe attack. Since *A. spiraecola* has long been recognized as a pest of crops and a vector of many plant diseases (Pirone, 1978), its abundance and distribution on *C. odorata* might lead to the infestation of citrus and other crops in nearby plantations or farms, and subsequently result in a pest outbreak. The percentage of aphid-infested *C. odorata* plants was usually higher compared to non-infested plants (Fig. 1).

*Aphis spiraecola* was present on every sampling occasion of the study, agreeing with Pfeiffer (1991), who reported that the aphid breeds throughout the year. The population was highest during the first sample (August) and declined over the five months sampled thereafter. This decrease in the aphid population over time was negatively correlated with temperature ($y = -0.0126x + 30.386$, $R^2 = 0.8704$, $P < 0.001$) and positively correlated with relative humidity ($y = 0.0313x + 77.565$, $R^2 = 0.771$, $P < 0.001$). An understanding of the role and interaction of these climatic factors assist in pest management decision-making. The occurrence of *A. spiraecola* throughout the year is of concern in crop systems as it can cause year-round damage to crops. In addition, high populations of the aphid may cause severe attack to crops, resulting in crop loss and food insecurity in a region already suffering from food scarcity.

Relationship between *Aphis spiraecola* and *Chromolaena odorata*

There was a significant ($P < 0.001$) correlation between numbers of *A. spiraecola* and mottled *C. odorata* leaves (Fig. 2), indicating that the mottled appearance is caused by *A. spiraecola*. As the population of *A. spiraecola* increases, the number of aphid-infested *C. odorata* plants and the number of mottled leaves also increases (Oigiangbe et al., 2007). Both nymphs and adults of *A. spiraecola* fed on the young, succulent terminal shoot-tips and their feeding activity always resulted in the mottling of *C. odorata* leaves. Oigiangbe et al. (2007) found similar results in a study of the association between some insects and the weed. As high populations of *A. spiraecola* cause curling of citrus foliage and can also stunt tree growth, especially on young trees (Pfeiffer et al., 1989), the widespread occurrence of *C. odorata* in plantations raises the fear that *A. spiraecola* may become an important pest or vector of some tree crop diseases in Nigeria (Uyi, 2005).

There was a significant ($P < 0.001$) positive linear relationship between *A. spiraecola* and *C. africana* (Fig. 3). This ant species was observed on the aphid-infested parts of plants, feeding on honeydew produced by the aphids. The relationship between ants and homopterans is mutualistic with the homopterans providing energy-rich honeydew for the ants which in turn protects and transports the former (Nixon, 1951; Strickland, 1951).

The need to control *Chromolaena odorata* in Nigeria

The above results show that *C. odorata* acts as a reservoir for *A. spiraecola*. Since *C. odorata* is extremely widespread and abundant, it is possible that it may allow *A. spiraecola* to become a serious pest of crops in Nigeria and other countries in the West African sub-region where *C. odorata* is invasive, hence there is a need to establish a control and management.
programme for *C. odorata* in Nigeria and elsewhere. *Chromolaena odorata* has also been reported to harbour *Z. variegatus*, an important pest of many crops in the sub-region (Uyi, 2005).

Apart from *C. odorata* harbouring *A. spiraecola*, which is a potential risk to crops, the weed is known to decrease the carrying capacity and species diversity in grassland and forests (Macdonald, 1984; Erasmus, 1985; Byford-Jones, 1989) and it also impacts negatively on agricultural productivity (Timbilla and Braimah, 2000). Considering that the problem of *C. odorata* is too ecologically and economically significant to be ignored, an integrated approach is needed for the control and management of the weed. Uyi (2008) recommended the release of large numbers of the leaf feeder *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae) and other agents such as the stem-galling fly *Cecidochara connexa* Macquart (Diptera: Tephritidae) that can attack the vegetative parts of the weed to reduce seedling establishment and the density of *C. odorata* stands. NIFOR initiated and funded the original research on biological control of *C. odorata* by the Commonwealth Institute for Biological Control in Trinidad in the 1960s, and two biocontrol agents, *P. pseudoinsulata* and the flower feeding *Apion brunneostrum* Beguin-Billecoq (Coleoptera: Curculionidae), were released in Nigeria in the early 1970s. However, neither established and no further biocontrol efforts have been undertaken since (Julien and Griffiths, 1998). The spread and distribution of the weed poses serious problems to agriculture and biodiversity in the southern part of Nigeria. Therefore, it is recommended that a biological control programme using *P. pseudoinsulata* and *C. connexa* should be initiated to tackle this invasive weed.

In conclusion, the abundance and occurrence of *A. spiraecola* on the ever-increasing *C. odorata* infestations pose a potential threat to citrus plantations, eggplant and other crops, which are suitable hosts for this insect. Biological control and management of *C. odorata* is highly recommended, because it will help reduce the pestilence of the known crop pests *A. spiraecola* and *Z. variegatus*.

**ACKNOWLEDGMENTS**

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Recommendations of the Seventh International Workshop on Biological Control and Management of Chromolaena odorata and Mikania micrantha, Taiwan, 12-15 September 2006

1. Governments of all countries affected by chromolaena are encouraged to consider the introduction of Cecidochares connexa.

2. Governments of all countries affected by chromolaena and mikania are encouraged to send representatives to the next workshop.

3. Regional organizations e.g. SPC and countries affected to produce public awareness material on chromolaena for identification and containment and control measures.

4. Countries should increase awareness of, and promote, biological control of weeds and its benefits.