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CHANGES IN SPECIES DIVERSITY, COMPOSITION, GROWTH AND REPRODUCTIVE PARAMETERS OF NATIVE VEGETATION INVADED BY *CHROMOLAENA ODORATA* AND *TITHONIA DIVERSIFOLIA* IN OSUN STATE, SOUTHWEST NIGERIA

O.O. Agboola[1]* and J.I. Muoghalu[2]

[1]Department of Botany, University of Lagos, Akoka, Yaba, Lagos State Nigeria

[2]Department of Botany, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

*Corresponding author: dareagboola@unilag.edu.ng, dipod2001@yahoo.com

ABSTRACT

Chromolaena odorata (L.) King & H.E. Robins and *Tithonia diversifolia* (Hemsl.) A.Gray are highly aggressive invaders in many parts of the tropics, especially in South-West Nigeria. The impact of both species on the diversity and floristic compositions of native species was evaluated. Relative to the uninvaded (control) plots, the average number of plant species in *Chromolaena* and *Tithonia* invaded plots was reduced by 31.6 % and 25.4 % respectively; Shannon-Wiener diversity was reduced by 13 % and 27 % respectively; species evenness was reduced by 10.5 % and 24.9 % respectively. Sorensen similarity of index between invaded and uninvaded plots for *Chromolaena* and *Tithonia* were 43.8 % and 32.6 % respectively. The number of native species was greatly reduced in areas invaded by *C. odorata* than in *T. diversifolia* invaded areas, leading to reduced species diversity and evenness. Reproductive parameters including mean number of flowers per plant, mean number of fruits per plant, mean number of seeds per fruit, mean weight of seeds and mean weight of each seed of the native species in the uninvaded plots were higher than those of the invaded plots for *Tithonia diversifolia* and *Chromolaena odorata*. The height of all native species in the uninvaded plots were taller than those of the invaded plots for *T. diversifolia* and *C. odorata*. It was concluded that invasion by *C. odorata* and *T. diversifolia* greatly affected the diversity of the native plant species with a corresponding reduction in their growth and reproductive parameters.

Keywords: Height, Evenness, Species diversity, Impact, invasion

INTRODUCTION

Biological invasions have become a major focus in the fields of ecology, biogeography and conservation biology (Richardson and Pysˇek, 2008). It is widely recognized that invasive exotic species threaten biological diversity and ecosystem function (Crawley *et al*., 1999; Mack *et al*., 2000; Mooney and Hobbs, 2000), but their specific impacts on, and their relationship with, diversity remains insufficiently studied across spatial scales (Stohlgren *et al.*, 2008; Spyreas *et al.*, 2010). The relationship between native and exotic richness and the homogenization of biological communities by exotic species are two key issues under debate in invasion ecology (Richardson *et al*., 2005; Olden, 2006). Invasive plants are important threats to biodiversity that influence natural ecosystems through both direct and indirect impacts on communities (Mattos, 2009), they alter the structure and composition of vegetation (Sakai *et al*., 2001). Changes in habitat structure caused by introduced invasive plant species can have effect on the resource distribution and vegetative allocation of native species. Invasive species are considered by the International Union for Conservation of

Nature (IUCN) as the second leading cause of species extinction after fragmentation and habitat destruction.

The Convention on Biological Biodiversity (CBD) recognised the need for the "compilation and dissemination of information on alien species that threaten ecosystems, habitats, or species to be used in the context of any prevention, introduction and mitigation activities", and calls for "further research on the impact of alien invasive species on biological diversity" (CBD, 2000). The objective set by Aichi Biodiversity Target 9 is that "by 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment". This reflects Target 5 of the EU Biodiversity Strategy (EU, 2011). With limited funding, it is necessary to prioritise actions for the prevention of new invasions and for the development of mitigation measures. This requires a good knowledge of the impact of invasive species on ecosystem services and biodiversity, their current distributions, and the pathways of their introduction (Molnar *et al*., 2008; Katsanevakis *et al*., 2013; Galil *et al*., 2014).

Notably among these species is *Tithonia diversifolia* (Hemsly) A. Gray (Asteraceae), commonly called Mexican sunflower, is a common shrub (weed) native to Central America but has become naturalized in many parts of the tropics, notably in south-west of Nigeria. *Tithonia diversifolia* is an invasive, annual weed, growing aggressively along road path, abandoned farmlands and hedges all over Nigeria (Shokalu, 1997). *Chromolaena odorata* is one of the worst weeds in the world, affecting agriculture and biodiversity in the tropical and subtropical regions of the Old World (Zachariades *et al*., 2009). *Chromolaena odorata* is fast spreading throughout the country especially in humid areas and displacing the native species from its habitat.

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Since the introduction of invasive alien species, they have become established in Nigeria and are fast spreading in the country. The existence, distribution and effects of these alien species on native species and ecosystem functions have not been investigated in Nigeria. However, there is paucity of knowledge on the effect of *C. odorata* and *T. diversifolia* on native plant terrestrial ecosystem, hence this study. The objectives for this study are to determine the effect of invasion by *C. odorata* and *T. diversifolia* on species diversity and richness and assess the impact of invasion on species composition, growth and reproductive parameters of resident species.

MATERIALS AND METHODS

Study Area

This study was carried out in Ile-Ife in southwestern Nigeria. Ile-Ife lies within latitudes 07°30' N to 07°35' N and longitudes 04°30' E to 04°35' E. The original vegetation of Ile-Ife has been described as lowland forest zone (Keay, 1959), semi deciduous moist forests (Charter, 1969) and Guineo-Congolian forest drier type (White, 1983). Hall (1969) also described the vegetation as the dry forest sub-group.

There are two prominent seasons in Ile-Ife area: rainy and dry season. The dry season is short, usually four months from November to March, and the longer rainy season prevails during the remaining months of the year. The weather report from the meteorological stations located within OAU Teaching and Research farm showed the annual rainfall at Ile-Ife averaged 1400 mm year^{-1} in a 5-year survey (Oke and Isichei, 1997) and mean annual temperature ranges from 22.5 to 31.4°C (Odiwe *et al*., 2012). The relative humidity in the early morning is generally high, usually over 90 % throughout the year. At mid-day it is rather lower, around 80 % in the wet season, as low as 50-60 % in the dry season (Hall, 1969)

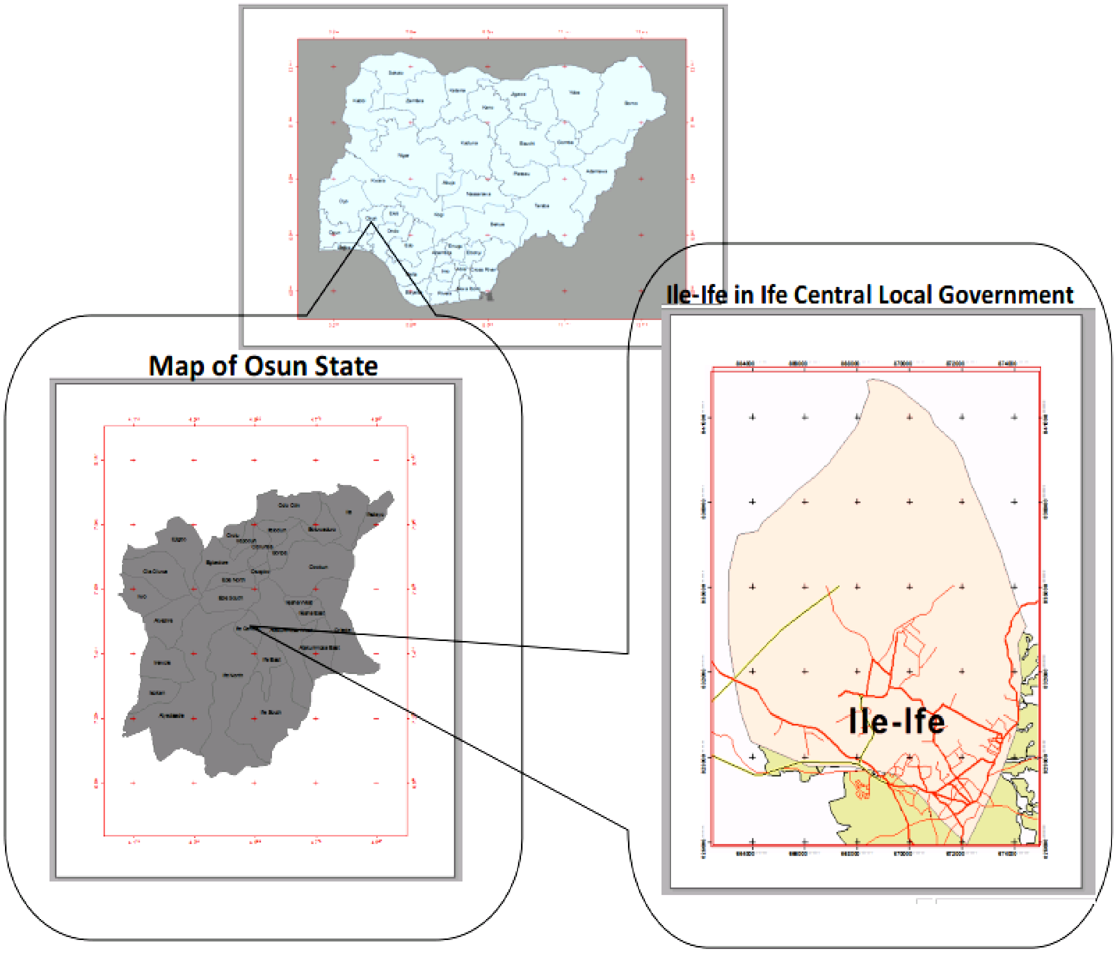

Figure 1: Location of Ile-Ife in Osun State, Nigeria.

Vegetation analysis An extensive search of sites heavily invaded by *C. odorata* and *T. diversifolia* in different locations at Ile-Ife was carried out. The choice of the sampling plots was based on the availability of *C. odorata* or *T. diversifolia* invaded plots with adjacent uninvaded plots for both species. Ten sampling locations were established for each of *C. odorata* and *T. diversifolia*. In each sampling location, a 10 m x 10 m transect was laid within the invaded and uninvaded portion. The invaded vegetation/ plot is where *C. odorata* or *T. diversifolia* was dominant and with >50% aerial cover, while the adjacent uninvaded portion is where neither *C. odorata* nor *T. diversifolia* had no cover (uninvaded plot). The uninvaded plot was chosen to have similar site conditions as possible to the invaded plot. In each plot, all species of vascular plants were identified to the species level. Specimens of plant species that could not be identified in the field were collected, pressed and identified in the IFE Herbarium. The species composition of the plots was established by listing the plant species encountered in each plot, summing up to get the total number of plant species for the plot. Authorities of botanical nomenclature follow the Flora of West Tropical Africa (Hutchinson and Dalziel, 1954-72). Three 10-m line transects were randomly established in each plot. Ground cover of plant species in the plot was measured at every 1 m interval along the transect. The number of 'hits' on each species was used to calculate the percentage cover of the species in the plot. Species cover was used as importance values for calculating the Shannon-Wiener diversity index (H') and evenness (J').

The Shannon diversity index (H') was used to characterize species diversity in each community or plot using the formula:

$H' = -\sum pi \ln pi$

Where $pi = \frac{ni}{N}$

ni = number of individuals of the species and N = Total number of individuals

Evenness was calculated as H'/InS, where S is the species richness expressed as the number of species. Differences in species richness, Shannon-Wiener index (H') and evenness (J') between invaded and uninvaded plots were used to measure the effect of invasion on these community characteristics.

The impact of invasion on species composition of resident species was assessed using Sorensen index of similarity (ISs) between the invaded and uninvaded plots was calculated based on species presence using the formula:

$$ISs = \frac{2C}{A+B} \times 100$$

Where C = number of species common to the plots

A = total number of species in invaded plot

B = total number of species in uninvaded plot

The total number of species recorded in all plots with invaded and uninvaded vegetations (S_{total}) of *C. odorata* and *T. diversifolia* were used as a measure of the impact of the invasion on species richness, S. This was expressed as the percentage reduction of the total number of species in invaded plots (S_{tot} inv) compared to that recorded in uninvaded plots (S_{tot} uninv = 100%). Positive value indicates a higher species number in uninvaded, negative in invaded vegetation.

The effects of population characteristics of the invading species on species richness at the plot scale was assessed using the invader's (*C. odorata* and *T. diversifolia*) height (cm) and cover (%) measured in each invaded plot. The impact of the invasive species on the height and ground cover of the native plant species was determined.

RESULTS

Impact of *Tithonia diversifolia* and *Chromolaena odorata* invasion on plant species composition and structure of invaded communities

The invasion of *Tithonia diversifolia* reduced the species composition of the invaded communities by 25.4 %, from 59 species in the uninvaded area to 44 species in the invaded area (Table 1). The invasion of *Chromolaena odorata* affected the species diversity and species composition of plant communities. The number of plant species was reduced from 57 (in the uninvaded communities) to 39 (in the invaded communities) (Table 2). This accounted for 31.58 % reduction the number of species in the *C. odorata* invaded area compared to the uninvaded area. The similarity index of the communities in the invaded and uninvaded areas was only 32.6 % (Table 3), which shows a clear indication of loss of species due to invasion of *T. diversifolia*. The Shannon-Weinner diversity of the *T. diversifolia* for uninvaded sites was 2.984 while it was 2.179 in the invaded sites. This is a reduction of 27.0 % in species diversity as a result of invasion (Table 3). The similarity index of the invaded and uninvaded areas was 43.75 %, showing a decrease in species composition due to invasion of *C. odorata*. The Shannon-Weinner diversity decreased by 13.0 % from 2.7494 in uninvaded communities to 2.3927 in *C. odorata* invaded communities (Table 3). The index of evenness in species distribution showed that the species were more evenly distributed in the uninvaded communities (0.7404) than in the *C. odorata* invaded communities (0.6627) (Table 3). The difference in index of evenness of species accounted for 10.5 % reduction in the invaded area. Species evenness was significantly decreased from 0.8036 in uninvaded to 0.6035 in invaded communities (24.9 % reduction) due to the invasion of *Tithonia diversifolia* (Table 3). Of the 34 families enumerated in *T. diversifolia* invaded and uninvaded sites, Fabaceae had the highest number (9) of species. Twenty-five (25) of these families were present in uninvaded plots while the invaded plots had 24 species. Fifteen families common to both the invaded and uninvaded plots of *T. diversifolia* are Acanthaceae, Amaranthaceae, Apocynaceae, Araceae, Celastraceae, Combretaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Icacinaceae, Malvaceae, Piperaceae, Poaceae, Sapindaceae and Sterculiaceae. A total of 34 families were enumerated in both the invaded and uninvaded sites for *C. odorata*. Eighteen families common to *C. odorata* invaded and uninvaded sites are Acanthaceae, Amaranthaceae, Apocynaceae, Asteraceae, Combretaceae, Connaraceae, Convolulaceae, Dioscoreaceae, Euphorbiaceae, Fabaceae, Malvaceae, Menispermaceae, Moraceae, Papilionaceae, Poaceae, Rubiaceae, Tiliaceae, Verbenaceae, and Vitaceae.

Table 1: Species composition in *Tithonia diversifolia* invaded (I) and uninvaded (U) plant communities in Ile-Ife, southwest Nigeria

S/No	PLANT SPECIES	FAMILY	U	I
1	*Abutilon sp.*	Malvaceae	-	+
2	*Anchomanes difformis*	Araceae	-	+
3	*Achyranthes aspera*	Amaranthaceae	+	-
4	*Aeschynomene indica*	Papilionaceae	+	+
5	*Albizia angertifolia*	Mimosaceae	+	-
6	*Albizia zygia*	Mimosaceae	+	+
7	*Alchornea laxiflora*	Euphorbiaceae	+	+
8	*Allophylus africanus*	Sapindaceae	+	-
9	*Alternanthera sessilis*	Amaranthaceae	+	-
10	*Andropogon gayanus*	Poaceae	+	-
11	*Aneilema beniniensese*	Commelinaceae	-	+
12	*Aspilia Africana*	Asteraceae	-	+
13	*Asystasia gangetica*	Acanthaceae	-	+
14	*Blighia unijugata*	Sapindaceae	+	-
15	*Bridelia micrantha*	Euphorbiaceae	+	-
16	*Calopogonium mucunoides*	Papilionaceae	+	+
17	*Chasmanthera dependens*	Menispermaceae	+	-
18	*Chassalia kolly*	Rubiaceae	-	+
19	*Chromolaena odorata*	Asteraceae	-	+
20	*Cissus argueta*	Vitaceae	-	+
21	*Combretum nigricans*	Combretaceae	+	+
22	*Cnestis ferruginea*	Connaraceae	-	+
23	*Croton bonplandianum*	Euphorbiaceae	+	+
24	*Croton zambesicus*	Euphorbiaceae	-	+
25	*Cucurbita sp*	Cucurbitaceae	+	-
26	*Culcasia scandens*	Araceae	+	-
27	*Cynodon dactylon*	Poaceae	+	+
28	*Cyathula prostrate*	Amaranthaceae	+	+
29	*Deinbolia pinnata*	Sapindaceae	-	+
30	*Desmodium gangeticum*	Papilionaceae	+	+
31	*Digitaria sp.*	Poaceae	+	-
32	*Dioscorea dumetorum*	Dioscoreaceae	+	-
33	*Euphorbia heterophylla*	Euphorbiaceae	+	+
34	*Euphorbia hirta*	Euphorbiaceae	+	-
35	*Ficus exasperata*	Moraceae	-	+
36	*Gloriosa superba*	Liliaceae	+	-
37	*Glyphaea brevis*	Tiliaceae	+	-
38	*Holarrhena floribunda*	Apocynaceae	-	+
39	*Icacina trichantha*	Icacinaceae	+	-
40	*Indigofera trifoliate*	Papilionaceae	+	-
41	*Ipomoea carnea*	Convolvulaceae	+	-
42	*Jateorhiza macrantha*	Menispermaceae	+	-

43	*Justicia insularis*	Acanthaceae	+	-
44	*Luffa cylindrical*	Cucurbitaceae	-	+
45	*Mallotus oppositifolius*	Euphorbiaceae	-	+
46	*Margaritaria discoidea*	Euphorbiaceae	+	-
47	*Mariscus alternifolius*	Cyperaceae	+	-
48	*Merremia sp.*	Convolvulaceae	+	-
49	*Mezoneuron benthamianus*	Caesalpinaceae	+	-
50	*Millettia thonningii*	Papilionaceae	+	-
51	*Mimosa pudica*	Papilionaceae	+	+
52	*Mondia whitei*	Periplocaceae	+	-
53	*Mormodica charantia*	Cucurbitaceae	-	+
54	*Mucuna pruriens*	Papilionaceae	+	-
55	*Newbouldea laevis*	Bignonaceae	+	-
56	*Panicum maximum*	Poaceae	+	-
57	*Paulina pinnata*	Sapindaceae	-	+
58	*Pouzolzia guineensis*	Urticaceae	+	-
59	*Pennisetum purpureum*	Poaceae	+	+
60	*Peperonea pellucida*	Piperaceae	+	+
61	*Phaulopsis sp.*	Acanthaceae	+	-
62	*Pleioceira barterii*	Apocynaceae	+	-
63	*Pyrenacantha staudtii*	Icacinaceae	-	+
64	*Rottboellia exaltata*	Poaceae	-	+
65	*Rotboellia cochinchinensis*	Poaceae	+	-
66	*Salacia chinensis*	Celastraceae	+	-
67	*Salacia pallescens*	Celastraceae	+	+
68	*Securinega virosa*	Euphorbiaceae	+	+
69	*Senna hirsuta*	Ceasalpinaceae	+	-
70	*Sida acuta*	Malvaceae	+	+
71	*Sida corymbosa*	Malvaceae	-	+
72	*Sida urena*	Malvaceae	-	+
73	*Smilax kraussiana*	Smilacaceae	-	+
74	*Spigelia anthelmia*	Loganiaceae	-	+
75	*Spondias mombin*	Anacardiaceae	+	-
76	*Sporobolus pyramidalis*	Poaceae	+	-
77	*Stachytarpheta angustifolia*	Verbenaceae	+	-
78	*Sterculia tragacantha*	Sterculiaceae	+	-
79	*Synedrella nodiflora*	Asteraceae	+	+
80	*Talinum triangulare*	Portulacaceae	-	+
81	*Tithonia diversifolia*	Asteraceae	-	+
82	*Tridax procumbens*	Asteraceae	+	+
83	*Urena lobata*	Malvaceae	+	-
84	*Vigna gracilis*	Papilionaceae	+	-
85	*Voacanga africana*	Apocynaceae	-	+
	TOTAL		**59**	**44**

*KEY: U: UNINVADED,   I: INVADED

Table 2: Species composition of *Chromolaena odorata* invaded (I) and uninvaded (U) plant communities in Ile-Ife, Southwest Nigeria

S/No	Name of Plants	FAMILY	U	I
1	*Achyranthes aspera*	Amaranthaceae	+	_
2	*Aeschynomene indica*	Papilionaceae	+	+
3	*Ageratum conyzoides*	Asteraceae	+	_
4	*Albizia lebeck*	Mimosaceae	+	+
5	*Albizia zygia*	Mimosaceae	_	+
6	*Alchornea laxiflora*	Euphorbiaceae	+	_
7	*Andropogon gayanus*	Poaceae	+	_
8	*Aspilia africana*	Asteraceae	+	+
9	*Asystasia gangetica*	Acanthaceae	+	+
10	*Axonopus compressus*	Poaceae	+	_
11	*Calopogonium mucunoides*	Papilionaceae	+	_
12	*Capsicum frutescens*	Piperaceae	+	_
13	*Carica papaya*	Caricaceae	+	_
14	*Chassalia kolly*	Rubiaceae	_	+
15	*Chochorus aestuans*	Tiliaceae	+	_
16	*Chromolaena odorata*	Asteraceae	+	+
17	*Cissus sp.*	Vitaceae	_	+
18	*Cnestis ferruginea*	Connaraceae	+	_
19	*Combretum nigricans*	Combretaceae	+	+
20	*Crotalaria retusa*	Papilionaceae	+	+
21	*Dalbergia sexatilis*	Papilionaceae	+	_
22	*Delonix regia*	Fabaceae	_	+
23	*Dichapetalum barteri*	Dichapetalaceae	+	_
24	*Digitaria sp.*	Poaceae	+	+
25	*Dioscorea bulbiferum*	Dioscoreaceae	+	+
26	*Dioscoroephyllum cumminsii*	Menispermaceae	_	+
27	*Dissotis rotundifolia*	Melastomataceae	+	_
28	*Euphorbia heterophylla*	Euphorbiaceae	_	+
29	*Ficus exasperata*	Moraceae	+	+
30	*Funtumia elastica*	Apocynaceae	_	+
31	*Gomphrena celosioides*	Amaranthaceae	+	+
32	*Grewia sp.*	Tiliaceae	_	+
33	*Holarrhena burefenum*	Apocynaceae	+	_
34	*Holarrhena floribunda*	Apocynaceae	_	+
35	*Hyptis rhomboides*	Lammiaceae	_	+
36	*Icacina trachantha*	Icacinaceae	+	_
37	*Ipomoea asarifolia*	Convolvulaceae	_	+
38	*Ipomoea involucrata*	Convolvulaceae	+	+
39	*Jateorhiza macrantha*	Menispermaceae	+	_
40	*Manihot esculenta*	Euphorbiaceae	+	_

41	*Mariscus alternifolius*	Cyperaceae	_	+
42	*Melochia corchoritolia*	Sterculiaceae	+	_
43	*Millettia thonningii*	Fabaceae	+	+
44	*Momordica charantia*	Cucurbitaceaae	+	_
45	*Mondia whitei*	Periplocaceae	_	+
46	*Mucuna pruriens*	Papilionaceae	+	_
47	*Panicum maximum*	Poaceae	+	_
48	*Parquetina nigrescens*	Periplocaceae	+	_
49	*Passiflora foetida*	Passifloraceae	_	+
50	*Pennisetum purpureum*	Poaceae	+	+
51	*Pouzolzia guineensis*	Urticaceae	_	+
52	*Rauvolfia vomitoria*	Apocynaceae	_	+
53	*Ricinodendron heudeloti*	Euphorbiaceae	+	_
54	*Salacia pallescens*	Celastreaceae	+	_
55	*Salvia coccinea*	*Lammiaceae*	+	_
56	*Schrankia leptocarpa*	Mimosaceae	+	+
57	*Securinega virosa*	Euphorbiaceae	+	_
58	*Senna podocarpa*	Ceasalpinaceae	+	_
59	*Sida acuta*	Malvaceae	+	+
60	*Sida corymbosa*	Malvaceae	+	+
61	*Sida urens*	Malvaceae	+	_
62	*Sida veronicifolia*	Malvaceae	+	_
63	*Solanum erianthum*	Solanaceae	+	_
64	*Spathodea campanulata*	Bignoniaceae	+	_
65	*Stachytarpheta angustifolia*	Verbenaceae	+	+
66	*Stylosanthes fruticosa*	Papilionaceae	_	+
67	*Talinum triangulare*	Portulacaceae	_	+
68	*Tithonia diversifolia*	Asteraceae	+	+
69	*Trema orientalis*	Ulmaceae	+	_
70	*Tridax procumbens*	Asteraceae	+	_
71	*Triumfetta cordifolia*	Tiliaceae	+	_
72	*Vigna gracilis*	Fabaceae	+	+
73	*Voacanga africana*	Apocynaceae	+	_
74	*Waltheria indica*	Sterculiaceae	+	+
	TOTAL		**57**	**39**

*KEY: U: UNINVADED, I: INVADED

Table 3: Impact of *Chromolaena odorata* and *Tithonia diversifolia* on community characteristics of invaded sites

Parameters	*Chromolaena odorata*			*Tithonia diversifolia*		
	U	I	Impact	U	I	Impact
Total Species	57	39	(-)31.6	59	44	(-)25.4
Richness	41	37	(-)9.8	25	24	(-)4.0
Shannon's Index of Diversity (H')	2.7494	2.3927	(-)13.0	2.9836	2.1787	(-)27.0
Index of Evenness (Es)	0.7404	0.6627	(-)10.5	0.8036	0.6035	(-)24.9
Similarity Index		43.8%			32.6%	
Dissimilarity Index		56.3%			67.4%	

*KEY: U: UNINVADED, I: INVADED

Table 4: Reproductive parameters of native species in invaded and uninvaded sites of *Tithonia diversifolia*

Reproductive parameter	*Euphorbia heterophylla*		*Aspilia africana*		*Sida acuta*	
	Inavded	Uninvaded	Invaded	Uninvaded	Invaded	Uninvaded
Mean number of flowers per plant	17.1 ± 5.7^{a}	28.4 ± 6.9^{c}	24.8 ± 9.6^{a}	56.7 ± 8.7^{b}	11.3 ± 5.7^{b}	19.1 ± 9.2^{c}
Mean number of fruits per plant	8.3 ± 3.1^{a}	12.4 ± 4.1^{a}	18.1 ± 3.7^{b}	21.4 ± 9.3^{b}	6.4 ± 1.6^{c}	10.8 ± 6.1^{c}
Mean number of seeds per fruit	19.7 ± 2.3^{a}	32.6 ± 4.3^{a}	28.2 ± 3.1^{a}	39.1 ± 5.7^{b}	17.4 ± 2.1^{c}	19.9 ± 4.1^{c}
Mean weight of 100 seeds (g)	0.21 ± 0.1^{a}	0.39 ± 0.14^{a}	0.33 ± 0.05^{a}	0.49 ± 0.05^{b}	0.23 ± 0.09^{c}	0.41 ± 0.09^{b}
Mean weight of each seed (g)	0.002	0.004	0.003	0.005	0.002	0.004
Height (m/plant)	1.85 ± 0.21^{a}	2.19 ± 0.80^{a}	2.08 ± 0.11^{b}	2.32 ± 0.40^{b}	1.18 ± 0.26^{c}	1.37 ± 0.43^{c}

*Values are mean ± 95% Confidence Interval. **Values with the same superscript along the same row are not significantly different

Table 5: Reproductive parameters of native species in invaded and uninvaded sites of *Chromolaena odorata*

Reproductive parameter	*Aspilia africana*		*Securinega virosa*		*Asystasia giangitica*	
	Inavded	Uninvaded	Invaded	Uninvaded	Invaded	Uninvaded
Mean number of flowers per plant	20.7 ± 8.2^a	42.3 ± 7.2^b	18.4 ± 6.8^a	31.4 ± 5.4^c	21.3 ± 9.5^a	40.5 ± 6.3^b
Mean number of fruits per plant	13.2 ± 4.1^a	20.6 ± 7.4^a	10.5 ± 2.8^b	16.7 ± 4.8^b	13.8 ± 3.4^c	18.5 ± 6.1^c
Mean number of seeds per fruit	21.5 ± 2.7^a	33.4 ± 7.9^b	17.8 ± 3.2^a	31.2 ± 6.1^b	20.1 ± 3.0^a	28.5 ± 5.9^c
Mean weight of 100 seeds (g)	0.23 ± 0.06^a	0.36 ± 0.05^a	0.19 ± 0.04^b	0.29 ± 0.06^b	0.29 ± 0.09^c	0.38 ± 0.14^c
Mean weight of each seed (g)	0.002	0.004	0.002	0.003	0.003	0.004
Height (m/plant)	1.51 ± 0.23^a	1.96 ± 0.54^a	0.83 ± 0.12^b	1.21 ± 0.37^b	1.04 ± 0.37^c	1.17 ± 0.43^c

*Values are mean ± 95% Confidence Interval. **Values with the same superscript along the same row are not significantly different

Reproductive parameters and height of native species in invaded and uninvaded sites by *Tithonia diversifolia and Chromolaena odorata*

There was significant difference in the mean number of flowers per plant, mean number of seeds per fruit and mean weight of seeds for all the native species compared in the invaded and uninvaded plots for *Tithonia diversifolia* and *Chromolaena odorata*. The mean number of fruits per plant showed no significant difference for all the native species between invaded and uninvaded plots for *T. diversifolia* and *C. odorata* (Tables 4 and 5).

All the reproductive parameters (mean number of flowers per plant, mean number of fruits per plant, mean number of seeds per fruit, mean weight of seeds and mean weight of each seed) of the natives in the uninvaded plots were higher than those of the invaded plots for *T. diversifolia* and *C. odorata* (Tables 4 and 5). The height of all the native species in invaded and uninvaded plots for *T. diversifolia* and *C. odorata* showed no significant difference but all the native species in uninvaded plots were taller than those of the invaded plots for *T. diversifolia* and *C. odorata* (Tables 4 and 5).

DISCUSSION

Chromolaena and *Tithonia* being very competitive and allelopathic possess the ability to suppress existing vegetation and natural succession, ultimately reducing species richness (Goodall and Zacharias, 2002) which was noticed in the invaded sites of the two species in this study.

The result of higher species composition, diversity and evenness recorded in the uninvaded sites compared to the invaded site in *T. diversifolia* and *C. odorata* might be due to the competitive interactions and dispersal limitation (natural or anthropogenic disturbance) which favors non-native over the native thereby causing reduction in the species composition of the invaded sites for *Tithonia* and *Chromolaena*. Disturbances are known to play a key role in promoting plant invasions (Seabloom *et al*., 2003; Hobbs and Huenneke, 1992; Lonsdale, 1999 and Mack *et al*., 2000). It is likely that the vigorous growth of these two invasive species, with higher cover and taller height than native members of the invaded communities, might be responsible for their strong impact on the species richness and evenness. The decrease in species richness, and subsequently species diversity upon the invasion of *Tithonia* and *Chromolaena* might be related to the cover and height of these invading species.

Also, changes in species evenness may influence invasion resistance, productivity and most especially increase in local plant extinction rates as observed in this study which is in agreement with the findings of Wilsey and Potvin (2000) and Smith *et al.* (2004). This study showed that the invasion of *T. diversifolia* and *C. odorata* reduced the species composition of the invaded communities which might be due to competitive dominance of these invasive species on the native species. The findings of this study on the effect of these two invasive species showed they suppress the established native species through competitive dominance. This assertion is in agreement with the findings of Maron and Marler (2008) which showed that three non-native grassland invaders in the western U.S. directly suppressed established native species through competitive dominance.

The establishment of *T. diversifolia* and *C. odorata* in the invaded sites might indicate that these invasive species are threat to the sustainability of native communities in that they alter their structure, composition and functions. The decrease in plant diversity and composition observed in this study in invaded sites of both *T. diversifolia* and *C. odorata* is in agreement with the findings of Norgrove *et al.* (2008) who reported that community composition was affected as a result of loss of monocotyledonous species and co-invasion by some dicotyledonous alien weed species which resulted from invasion of *C. odorata* in Cameroon.

It must be pointed out that invasion by *T. diversifolia* had higher impact on evenness and diversity of the native species compared with *C. odorata.* This can be due to the ability of *T. diversifolia* to form homogenous stands which seems to be another effective means of suppressing native vegetation thereby reducing the evenness and diversity of the native species as observed. This findings is in agreement with the observation of Hejda *et al*. (2009) where *Heracleum mantegazzianum* invasion suppressed the native vegetation due to its ability to form homogenous stands.

The observed reduction in the height of the native species in the invaded sites of *Tithonia and Chromolaena* might be attributed to the competitive effect of these invasive species on the native species by forming homogenous stand and their spread which hinder sunlight needed for production of food which aids growth. This might have been made possible because most of these native species in the invaded sites have been shaded by the canopy structure of these invasive species thus affecting light interception which is necessary for their photosynthesis to occur and for an appreciable growth in the native species. The reduction in the height of the native species in the invaded sites as compared to their height in the uninvaded sites for both *Chromolaena* and *Tithonia* as observed in this study can be linked to the findings of Woods (1993) who suggested that competition for light was responsible for the impact of Tatarian honeysuckle on the height of native understory herbs in a New England forest.

Tithonia diversifolia and *Chromolaena odorata* are observed to have canopy structure due to their large or higher leaf area which has helped them in production of larger photosynthetic product because leaf is known to be the part of the plant where larger proportion of photosynthesis takes place.

In the similar trend, the reproduction activity of the native species in the sites invaded by *T. diversifolia* and *C. odorata* have been affected in relation to their number of flower per plant, number of fruit per plant, number of seed per fruit and most especially, weight of the seeds. There is observed larger seed in terms of weight in the native species of the uninvaded sites being their native community which explain why they are fit and continue to spread in the uninvaded sites as compared to their small sized seeds which further leads to the reduction in species richness in the invaded sites. Larger seeded species might survive better in any environment because the additional metabolic reserves present in large seeds can buffer a carbon loss which is in support of the findings of Moles *et al.* (2005). The larger seeds may reflect an adaptation to dispersal by agents of dispersal some of which are extinct because large-seeded species are predicted to be better adapted to the catastrophic events encountered by seedlings because they can compensate for damage using seed reserve. The large heavier seed of native species in the uninvaded sites for *Tithonia* and *Chromolaena* as observed in this study implies that its embryo is large and it carries large food reserves. The large embryo and large food reserves of the seed of the native species in the uninvaded sites make it possible for the seedlings to emerge as a more completely developed plantlet, survive for longer and grow to a more appreciable size in an environment that is starved of resources.

Johnson and Cook (1998) have reported that since major proportion of the weight of a seed is food storage tissue, one may conclude that there is some optimum amount of food reserve which will normally insure the necessary seedling vigor. This probably accounts for the high species richness of the native species in the uninvaded sites for the two invasive species studied.

Indeed, larger-seeded woody species possess suites of attributes, such as greater leaf longevity and lower specific leaf area, which confer shade tolerance. In addition, large seeds tolerate both insect infestations of seed reserves as well as shoot damage which is in support of the findings of several authors such as Dalling *et al.* (1997) and Green and Juniper (2004). The results of this study in which the native species in the invaded sites with smaller seeds in size grow slower and have smaller height compared to those of the uninvaded sites for both *Tithonia* and *Chromolaena* is in contrary to the findings of Paz and Martinez-Ramos (2003) and Baraloto *et al*. (2005) where they expect that the smaller-seeded species will generally grow faster than larger-seeded species and thus overcome the initial size advantage associated with larger seed size. Our results suggest that large seed size is part of a suite of traits that enable the seedling to tolerate low resource availability and plasticity in root allocation in response to light availability which may enable the seedling to save resources for future growth.

CONCLUSION

This study provides rigorous evidence that alien plant species exert significant impacts on many ecological variables. The invasions of *T, diversifolia* and *C. odorata* have shown to have impact on species richness and diversity of the native species in the invaded sites by reducing the number of native species in the invaded sites when compared with the native species in uninvaded sites. The results of this study showed that the invasion of *T. diversifolia* and *C. odorata* drastically reduced the species composition, Shannon Weinner and index of evenness of the invaded communities by 25.4 %, 27 %, 24.9 % and 31.58 %, 13 %, 10.5 % respectively. The Similarity indices between the invaded and uninvaded plots for *T. diversifolia* and *C. odorata* were 32.6 % and 43.75 % respectively. In like manner, the invasion of these two species has shown to lessen the reproductive parameters and height of the native species in the invaded areas. The results of this study show that plant height is an important characteristic which could pose obvious effects on reproductive allocation strategy but not total biomass.

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REFERENCES

Baraloto, C., Forget, P.M. and Goldberg, D.E. (2005) Seed mass, seedling size and neotropical tree seedling establishment. Journal of Ecology 93: 1156-1166

CBD (Convention on Biological Diversity) (2000) Interim Guiding Principles. Conference of the Parties Decision V/8 Alien species that threaten ecosystems, habitats or species.

Charter, J.R. (1969) Map of Ecological zones of Nigerian Vegetation. Federal Department of Forestry Ibadan

Crawley, M.J. (1986). The population biology of invaders. *Phil Trans. R. Soc. Lond. B* 314: 711-731.

Dalling, J.W., Harms, K.E. and Aizprua, R. (1997) Seed damage tolerance and seedling resprouting ability of *Prioria copaifera* in Panama. Journal of Tropical Ecology 13: 481-490

EU (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM/2011/244, European Commission, Brussels, 16 pp

Galil, B.S., Marchini, A., Occhipinti-Ambrogi, A., Minchin, D., Narščius, A, Ojaveer, H. and Olenin, S. (2014) International arrivals: widespread bioinvasions in European Seas. Ethology Ecology and Evolution 26 (2-3): 152–171

Goodall, J.M. (2002) Managing *Chromolaena odorata* (chromolaena) in subtropical grasslands in KwaZulu-Natal, South Africa. In: Zachariades, C., Muniappan, R. and Strathie, L.W. (eds) *Proceedings of the Fifth International Workshop on Biological Control and Management of Chromolaena odorata*, Durban, October 2000.

Green, P.T. and Juniper, P.A. (2004). Seed–seedling allometry in tropical rain forest trees: seed mass-related patterns of resource allocation and the ‘reserve effect’. Journal of Ecology 92:397–408.

Hall, J.B. (1969) The vegetation of Ile-Ife. University of Ife. Herbarium Bulletin I.

Hejda, M., Pysek, P. and Jarosík, V. (2009) Impact of invasive plants on the species richness, diversity and composition of invaded communities. Journal of Ecology 97**:** 393–403

Hobbs, R.J. and Huenneke, L.F. (1992). Disturbance, diversity, and invasion: implications for conservation. Conservation Biology 6: 324–337.

Hutchinson, J. and Dalziel J.M. (1954-1972) Flora of West Tropical Africa (revised by Keay, R.W.J. and Happer F.N.). Crown Agents for oversees Government, London.

Johnson, M.P. and Cook, S.A. (1968) Clutch size in butter cups. American Naturalist 102: 405-411

Katsanevakis, S., Zenetos, A., Belchior, C. and Cardoso, A.C. (2013) Invading European Seas: assessing pathways of introduction of marine aliens. Ocean and Coastal Management 76: 64–74

Keay, R.W.J. (1959). An Outline of Nigerian vegetation 3rd edition. Federal Ministry of information printing division Lagos 46 pp

Lonsdale, W.M. (1999). Global patterns of plant invasions and the concept of invasibility. Ecology 80:1522-1536.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans H., Clout, M. and Bazzaz, F.A. (2000). Biotic invasions: Causes, epidemiology, global consequences, and control. Ecological Applications 10:689-710.

Maron, J.L. and Marler, M. (2008). Effects of native species diversity and resource additions on invader impact. American Naturalist 172: S18 – S33.

Moles, A.T., Ackerly, D.D., Webb, C.O., Tweddle, J.C., Dickie, J.B. and Pitman, A.J. (2005). Factors that shape seed mass evolution. Proceedings of the National Academy of Science USA, 102**:** 540–544.

Molnar, J.L., Gamboa, R.L., Revenga, C. and Spalding, M.D. (2008) Assessing the global threat of invasive species to marine biodiversity. Frontiers in Ecology and the Environment 6(9): 458–492

Mooney H.A. and Hobbs, R.J. (2000). Invasive species in a changing world. Island Press, Washington, D.C., U.S.A.

Norgrove, L., Yonghachea, P.F. and Csuzdi, C.S. (2008). Earthworm diversity and densities in land invaded by *Imperata cylindrica* and *Chromolaena odorata* in the Western Cameroon Highlands. In: *Pavlícek T. and Canet P. (eds) Advances in Earthworm Taxonomy III*. En Tipis Publishers. Nicosia, Cyprus pp. 163-173.

Odiwe, A.I., Olowoyo, J.O. and Ajiboye, O. (2012) Effects of Land-Use Change on Under Storey Species Composition and Distribution in Tropical Rainforest. Notulae Scientia Biologicae 4(1): 150-156

Oke, S.O. and Isichei, A.O. (1997) Floristic Composition and Structure of the fallow vegetation in Ile-Ife Area of South Western Nigeria. Nigerian Journal of Botany 10: 37-50

Olden, J.D. (2006) Biotic homogenization: a new research agenda for conservation biogeography. Journal of Biogeography 33: 2027-2039

Paz H. and Martínez-Ramos (2003) Seed mass and seedling performance within eight species of *psychotria* (Rubiaceae). Ecology 84 (2): 439-450

Richardson, D.M. and Pysˇek, P. (2008) Fifty years of invasion ecology: the legacy of Charles Elton. Divers Distrib 14:161–168

Sakai, A.K., Allendorf, F.W., Holt, J.S., Lodge, D.M., Molofsky, J., With, K.A., Baughman, S., Cabin, R.J., Cohen, J.E., Ellstrand, N.C., Mccauley, D.E., O'neil, P., Parker, I.M., Thompson, J.N. and Weller, S.G. (2001). The population biology of invasive species. Annual Review of Ecological Systematics 32: 305–332.

Seabloom, E.W., Harpole W.S., Reichman O.J., and Tilman D. (2003) Invasion, competitive dominance and resource use by exotic and native California grassland species. *Proceedings of the National Academy of Sciences of the USA* 100:13384–13389.

Smith, M.D., Wilcox, J.C., Kelly, T. and Knapp, A.K. (2004) dominance not richness determines invisibility of tall grass prairie. Oikos 106: 253-262

Spyreas, G., Wilm, B.W., Plocher, A.E., Ketzner, D.M., Matthews, J.W., Ellis, J.L. and Heske, E.J. (2010). Biological consequences of invasion by reed canary grass (*Phalaris arundinacea*). Biological Invasions, 12:1253-1267.

Stohlgren, T.J., Barnett, D.T., Jarnevich, C.S., Flather, C. and Kartesz, C. (2008) The myth of plant species saturation. Ecology Letters 11**:** 315–26;

Tilman, T.D. (1997) Human alteration of the global nitrogen cycle: sources and consequences. Ecological Applications 7:737– 750.

White, F. (1983). The vegetation of Africa. A descriptive memoir to accompany map of Africa. UNESCO, Paris 356pp.

Wilsey, B.J. and Potvin, C. (2000). Biodiversity and ecosystem functioning: importance of species evenness in an old field. Ecology 81: 887-892.

Woods, K.D. (1993). Effects of invasion by *Lonicera tartarica* L. on herbs and tree seedlings in four New England forests. – Am. Midl. Nat. 130: 62–74.

Zachariades, C., Day, M., Muniappan, R. and Reddy, G.V.P. (2009) *Chromolaena odorata* (L.) King and Robinson (Asteraceae). In Biological Control of Tropical Weeds Using Arthropods (eds. Muniappan, R., Reddy, G.V.P. & Raman, A.), pp. 130–162, Cambridge University Press, Cambridge, UK.