A novel alien invasive species introduction, *Clerodendrum paniculatum* Linn (Pagoda) Lamiaceae, in a tropical African forest

Omomoh Eromosele Bernard (✉ benomong@yahoo.com)

Federal University of Technology, Akure, Nigeria

Leah Brown

Insight Lab, Faculty of Information and Media Studies, Western University, London, Ontario, N6A 3K, Canada

Karst Meiger

Herbarium Frisicum Schoolstraat 19B8471 CC Wolvega Netherlands

Victor A. J. Adekunle

¹Department of Forestry and Wood Technology, Federal University of Technology, Akure, Nigeria

Ganiyu Oboh

FUTA herbarium, Centre for Research and Development (CERAD), Federal University of Technology, Akure, Nigeria

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Short Report

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Abstract

We record a novel introduction of *Clerodendrum paniculatum* in Africa. The novel species appears to have a negligible impact within the new environment. In this communication, we describe the novel alien species and the environment to which it has been introduced.

Introduction

The introduction of novel alien species into new habitats was not a global issue until such habitats began to lose three integral parts of biodiversity, such as ecosystem, species, and genetic diversity, to novel alien species (CBD 2009). Consequently, biological invasion introduces novel alien species to native plant communities (Satterthwaite et al. 2007), forms species colonies (Augusto et al 2001, Luzuriaga et al 2005), and causes differential characteristics in genetic validation, all contributing to biodiversity losses (McNeely et al 2001, Mack et al 2000). The losses brought about by novel alien species invasion are undoubtedly a critical issue in the world economy, specifically developing countries in Africa (Nuñez & Anibal 2010). Due to provenance variation, little is still known of the effective mechanism to eradicate the level of novel alien species invasion (Englberger 2009, Flory 2019) in developing countries. Therefore, biodiversity conservation of indigenous plant ecosystems requires obtaining an adequate sample of unperturbed ecosystem types of an endangered species in perpetuity, which becomes an example of the original forest that is used for the Strict Nature Reserve (Omomoh et al 2019, Adekunle et al 2013, Onyekwelu et al 2008). Incidentally, studies show that novel alien species colonize different protected areas such as Strict Nature Reserve (Wekhanya 2016, Lone 2019).

In the present study, an introduction of the alien plant species *Clerodendrum paniculatum* Linn, commonly known as Pagoda flower, and one of the 150 original species in the genus *Clerodendrum* was detected and collected for the first time in an African forest. *C. paniculatum* is abundant in tropical and subtropical Asia where it is commonly encountered and widely cultivated for its medicinal uses. There is no current information regarding the presence of *C. paniculatum* in Africa. Additionally, Iyama et al (2015) did not report any collections of this species either in forests, fields, or gardens, which places this plant among the lesser-known alien species in Nigeria (Adekunle 2009). The species is a well-known invader in several parts of the world (Englberger 2009), native to Europe and Australia, and is predominant in Asian countries like Bangladesh, Laos, China, Cambodia, Sri Lanka, Vietnam, Malaysia, Indonesia Taiwan (Prashith et al 2018, Leeratiwong 2011, Bhat 2014, Melapu 2015). The genus *Clerodendrum* (Linn.—F.T.A. 5: 292; B. Thomas in Engl. Bot. Jahrb. 68: 1.1936) was formerly placed in the family Verbenaceae but is now placed in the family Lamiaceae (Cantino et al., 1992 and Harley et al., 2004).

This genus is composed of c.a. 400 species of mostly shrubs or trees, erect or rarely climbing, deciduous or evergreen. They are found mostly in the tropics and sub-tropics across Asia, Europe, Africa, and the Americas (Shou-liang and Gilbert 1994). Thirty species have been recorded in Africa alone (FWTA 1963), 34 species across China (Shou-liang and Gilbert 1994). In Nigeria, 18 species are recorded according to Flora of West Tropical Africa, and 9 of these species are indigenous (Gbile et al 2002).

Materials And Methods

Sampling Design

In March 2020, we collected samples of *Clerodendrum paniculatum* at two sites; Forest plantation and Strict Nature Reserve at the forest reserve, Nigeria. Four temporary sample plots of 400m² (two at each site) were haphazardly selected along the vegetation road edge where *C. paniculatum* was found. The first 10m line of 400m² (20m by 20m) was stationed to start from the first *C. paniculatum*, where it was sighted at the spatial area from the road edge to the smaller spatial area of the site (adjacent to the road edge). The scientific name and family followed the flora of West Tropical Africa (Hutchinson et al 1963).

Data analyses

The plant species were categorized into their life forms using Hutchinson et al (1963). The percentage of species relative density was calculated using:

$$RD = (n_i/N) \times 100 \text{ (1)}$$

Where RD = species relative density,

n_i = number of individuals of species i ,

N = total number of all plant species in the entire community.

Specimen

We first discovered *C. paniculatum* while collecting specimens for herbarium collection (Omomoh et al 2019). We visually estimated *C. paniculatum* cover at each site. Specimens of flowering parts and leaves were collected in September of 2014, brought to the herbarium, and examined while still fresh. Latitude and longitude for each site were taken using a Garmin GPS 60. After a thorough plant examination, collections were identified as *Clerodendrum*. For more specific identification, we sent specimens to Aleksi Baznekian (Joseph Keefe Herbarium, USA), who identified the specimen as *C. paniculatum* L. Additionally, we cross-checked our specimen with the studies of Deori et al (2012) and Prashith & Sudharshan (2018).

Distribution in Nigeria: South West Ondo, Akure forest reserve

This Akure forest area is humid sub-tropical with a mean temperature of 26°C (range of 19°C - 34°C). The wet season is from March to November (2500 mm bimodal rainfall pattern) and the dry season from December to February (Omomoh 2018, Omomoh et al 2019, Omomoh et al 2020). The Akure forest reserve is a tropical successional rainforest situated between two communities, Aponmu and Obada in Owena. Local government encompasses the two study sites, Forest plantation, and Strict Nature Reserve, where the novel alien species was first located and collected.

The novel species is a tropical evergreen shrub that was found in dry and mixed deciduous forests along the major roadside in two different regions (Forest Plantation and marginal area of the Strict Nature Reserve; Figure 1). This part of the forest has been going through succession following human disturbance since the initiation of the forest reserve (Onyekwelu. et al 2008). The *C. paniculatum* species are more scanty and sturdy in the Strict Nature Reserve than in the Forest Plantation where the species was growing bigger and taller. The species height varied from one *C. paniculatum* to another (75cm to 1.3m) due to the degree of sunlight exposure received.

Diagnostic character

***Clerodendrum paniculatum* Linnaeus, Mant. Pl. 90. 1767.**

Shrubby tree (Figure 2, 3a and 3b) about 2 – 3 m high; stem stout in a square cross-sectional size or obtusely quadrangular. Flowering parts bear numerous large, red-orange, flowers with terminal inflorescences. The thyrses, called panicles, are often up to 45 cm long. The tubular flower is 1.2-2 cm long with five small lobes. The leaves are opposite, large at the base and becoming smaller upwards; sub-rotund to cordate at the base, and palmately lobed (3-7) at the margins.

Results And Discussion

Species richness and diversity of the study area

Considering the distribution of *Clerodendrum paniculatum* in several parts of the world as both native and invasive connotes that this novel alien species originates not from Africa, and nevertheless this study reveals where it was found in Africa for the first time. The different land-use type effects on species distribution and establishment in these new habitats gave us the larger number of species at one site over the other.

The total families are shown in Tables 1 & 2. Twenty-one (21) families were encountered within the Forest Plantation, and fifteen (15) in Strict Nature Reserve (SNR). This shows that between the two different sites, the family with the highest number of plant species was found in the legumimosae (Caesalpinoideae, Detariodeae, and Papilionideae) with 7 different plants species. But within the sites, plant numbers from Table 1 show *C. paniculatum* was the second most abundant plant species, with a relative density of 14.12%, after *Sida acuta* Burm. F., a native plant, with a relative density of 15.97%. The species comparison between the two tables shows that the proliferation of *C. paniculatum* was rather alarming in Table 2. The reason for this rapid growth and distribution may have been associated with what Randhi and Reddy (2013) described as an intermediate, tolerant, plant capacity in their study. Light and spatial distributions are associated factors more incidental to territorial adaptation and tolerance in the Forest Plantation than in the protected area of the Strict Nature Reserve. This is seen as a result of a partial or closed canopy in Strict Nature Reserve. This dynamic change is in corroboration with Lone *et al* (2019), which states “invasive species typically are more tolerant than the native species to a wide range

of environmental conditions and possess unique biological traits that offer them various competitive advantages.”

We estimated the Shannon-Weiner diversity index and species evenness for the two sites. The Strict Nature Reserve was less diverse and less even ($H'=2.48$, $E=0.41$) than the Forest Plantation ($H'=2.9$, $E=0.48$). Most of the species in the Forest Plantation are agricultural weeds (Perera, 2005).

Table 1. Plant species, relative frequency and relative density of Forest plantation

Family	Scientific name	Life form	nHa ⁻¹	RD
Acanthaceae	<i>Acanthus montanus</i> (Nees) T. Anders.	Forb	11	2.5
	<i>Asystasia vogeliana</i> Benth.	Forb	22	5.1
Amarantaceae	<i>Cyathula prostrata</i> (Linn.) Blume	Forb	36	8.3
Ampelidaceae	<i>Cissus kouandeensis</i> A. Chev.	Climber	13	3.0
	<i>Cissus petiolata</i> Hook. f.	Climber	2	0.5
Apocynaceae	<i>Holarrhena floribunda</i> (G. Don) Dur. & Schinz APD acc	Sapling	1	0.2
Araceae	<i>Culcasia scandens</i> P. Beauv.	Climber	22	5.1
Arecaceae	<i>Elaeis guineensis</i> Jacq.	Sapling	11	2.5
Asclepiadaceae	<i>Parquetina nigrescens</i> (Afzel.) Bullock	Climber	1	0.2
Asteraceae	<i>Chromolaena odorata</i> (L.) R. M. King & H. Rob.	Forb	13	3.0
	<i>Vernonia cinerea</i> (Linn.) Less.	Forb	9	2.1
Caesalpinioideae	<i>Acacia ataxacantha</i> DC.	Climber	5	1.2
	<i>Albizia adianthifolia</i> (Schum.) W. F. Wight	Sapling	1	0.2
	<i>Albizia zygia</i> (DC.) J. F. Macbr.	Sapling	1	0.2
	<i>Senna hirsuta</i> (L.) H.S. Irwin & Barneby	Sapling	2	0.5
Commelinaceae	<i>Aneilema beniniense</i> (P. Beauv.) Kunth	Forb	5	1.2
	<i>Commelina erecta</i> L. subsp. Erecta	Forb	3	0.7
Convolvulaceae	<i>Merremia aegyptia</i> (Linn.) Urban	Climber	2	0.5
Cucurbitaceae	<i>Momordica charantia</i> Linn.	Climber	11	2.5
Dioscoreaceae	<i>Dioscorea preussii</i> Pax	Climber	7	1.6
Euphorbiaceae	<i>Manihot esculenta</i> Crantz	Shrub	17	3.9
Lamiaceae	<i>Clerodendrum paniculatum</i> Linn	Sapling	61	14.1
	<i>Solenostemon monostachyus</i> var. <i>graniticola</i> (A. Chev.) Brenan	Forb	6	1.4
Malvaceae	<i>Sida acuta</i> Burm. f.	Forb	69	16.0
	<i>Sida urens</i> Linn.	Forb	9	2.1
Moraceae	<i>Ficus exasperata</i> Vahl	Sapling	1	0.2
Papilionoideae	<i>Centrosema pubescens</i> Benth.	Climber	14	3.2

	<i>Desmodium adscendens</i> (Sw.) DC. var. adscendens	Forbs	18	4.2
Poaceae	<i>Panicum maximum</i> Jacq.	Graminoid	31	7.2
Portulacaceae	<i>Talinum triangulare</i> (Jacq.) Willd.	Forb	17	3.9
Sterculiaceae	<i>Theobroma cacao</i> Linn.	Sapling	11	2.5

n ha⁻¹ = number of stems per hectares, RD = relative density.

Table 2. Plant species, relative frequency and relative density of Strict nature reserve

Family	Name	Life Form	nHa ⁻¹	RD
Amarantaceae	<i>Cyathula prostrata</i> (Linn.) Blume	Forb	81	19.8
Annonaceae	<i>Cleistopholis patens</i> (Benth.) Engl. & Diels	Sapling	11	2.689
	<i>Funtumia elastica</i> (Preuss) Stapf	Sapling	1	0.244
Apocynaceae	<i>Rauvolfia vomitoria</i> Afzel.	Sapling	2	0.489
Araceae	<i>Culcasia scandens</i> P. Beauv.	Forb	7	1.711
Asteraceae	<i>Tithonia diversifolia</i> Hemsl. A. Gray	Forb	78	19.07
Bombacaceae	<i>Ceiba pentandra</i> (Linn.) Gaertn.	Sapling	23	5.623
Detarioideae	<i>Anthonotha macrophylla</i> P. Beauv.	Sapling	4	0.978
Euphorbiaceae	<i>Mallotus oppositifolius</i> (Geisel.) Müll. Arg	Shrub	27	6.601
Lamiaceae	<i>Clerodendrum paniculatum</i> L.	Sapling	3	0.733
Meliaceae	<i>Entandrophragma utile</i> (Dawe & Sprague) Sprague	Sapling	17	4.156
	<i>Khaya grandifoliola</i> C. DC.	Sapling	48	11.74
Menispermaceae	<i>Jateorhiza macrantha</i> (Hook. f.) Exell & Mendonca	Climber	14	3.423
Polygalaceae	<i>Carpolobia lutea</i> G. Don	Sapling	14	3.423
Rubiaceae	<i>Cuviera longiflora</i> Hiern	Sapling	2	0.489
Sapindaceae	<i>Allophylus africanus</i> P. Beauv.	Sapling	8	1.956
	<i>Blighia sapida</i> Konig	Sapling	4	0.978
Sterculiaceae	<i>Cola gigantea</i> A. Chev. var. Gigantean	Sapling	3	0.733
	<i>Mansonia altissima</i> (A. Chev.) A. Chev. var. altissima	Sapling	32	7.824
	<i>Pterygota macrocarpa</i> K. Schum.	Sapling	2	0.489
	<i>Sterculia tragacantha</i> Lindl.	Sapling	2	0.489
	<i>Triplochiton scleroxylon</i> K. Schum.	Sapling	19	4.645

n ha⁻¹ = number of stems per hectares, RD = relative density.

Distribution and species range of Clerodendrum paniculatum at the study area

Clerodendrum paniculatum was identified in the Strict Nature Reserve and the Forest Plantation. *C. paniculatum* is becoming more adaptive in the Forest Plantation as land managers have stated that several efforts of attempting to remove *C. paniculatum* have not worked. *C. paniculatum* appears to be much more abundant in the Forest Plantation than in the Strict Nature Reserve.

Our studies have shown that *C. paniculatum*, though fewer in number, pose a threat to the current status of the Strict Nature Reserve. It may have been as a result of the great adaptability of this plant to interact with the native species of the stable forest (Omomoh et al 2019) at the forest edge. Open forest canopy can as well encourage wind-borne seed of novel alien species to proliferate in a new site (Perera 2005, Pickett & McDonnell 1989), as was in the case of Forest Plantation. This is certainly another prospective challenge in the management of the Strict Nature Reserve, as it may pose a greater danger of extinction to native biodiversity hereafter.

Species presence on the new environment

This study is the first report of *C. paniculatum* in Africa. It does not currently appear to have a large impact on the community that it is novel to, and thus we do not currently categorize this plant species as an 'invasive'. Despite this, *C. paniculatum* is currently cited as invasive in the following countries: Singapore, Cuba, Hawaii, French Polynesia, Micronesia, Fiji, Palau, New Guinea, the Solomon Islands, and Western Samoa (CAB 2020). Previous research has shown that the invasiveness of *C. paniculatum* is driven in part via its root proliferation ability (Chong et al 2009, Randall 2017, Pier 2020, Powo 2020, Oviedo & Gonzalez-Oliva 2015). Our current assessment of *C. paniculatum* as a novel alien species with non-problematic impact (Williamson 1999) is similar to the Davis and Thompson (2000) type 3 and 7 colonizer categories.

Although novel species range expansion on these new regions is not invasive, unexpected mass dispersal resulting in expansion of their range (e.g., environmental change) following long time disturbance could quickly lead to invasion. Consequently, Engiberger (2009) reported the phytogeographical scenario of this plant in Oceania: French Polynesia, Guam, Marshall Island, Nauru, Palau Papua, New Guinea, Samoa, and the Solomon Islands. The Federated States of Micronesia lists *C. paniculatum* as distributed across the islands of Pinpelap, Pohnpei, and Chuuk. Nevertheless, reports of novel alien species colonization in new areas could greatly assist conservation efforts in mitigating invasions at the early stage in Africa. However, little or lack of scientific information on invasive plant species in developing countries leads to a shortfall in scientific data for international uses (Nuñez & Pauchard 2010, Nuñez. et al 2019). To overcome this challenge, a collaboration between countries and researchers is needed to address this emerging menace by identifying and sharing scientific information on novel alien species in different jurisdictions, as well as current best management practices to handle them (Brundu et al 2020).

Declarations

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Conflict of Interest

We have no conflict of interests.

Orcid

Bernard. E. Omomoh <https://orcid.org/0000-0002-0506-4973>

Data Availability

Nil

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Figures

Figure 1

Map of the two study sites. The green area showed the specific study area while the points, Strict Nature Reserve (SNR) and Owena (Forest Plantation) depict the points where the studies were carried out.

Figure 2

(a) *Clerodendrum paniculatum* Linnaeus (b) Flowering branch, (c) Fruit. (Chen et al 1994). Systematics reference: *Clerodendrum paniculatum* L, Mant. Pl. 1: 90. 1767; Blume, Bijdr. Fl. Ned. Ind.: 811. 1826; Walp., Repert. Bot. Syst. 4: 102. 1845; Schauer in A. DC., Prodr. 11: 668. 1847; Miq., Fl. Ind. Bat. 2: 879. 1858; C.B. Clarke in Hook.f., Fl. Brit. India 4: 593. 1885; Brandis, Indian Trees: 508. 1906; King & Gamble, J. Asiat. Soc. Bengal 74: 838. 1909; Hall.f., Meded. Rijks-Herb. 37: 81. 1918; H.J. Lam, Verben. Malay. Archip.: 295. 1919; Bakh. in H.J. Lam & Bakh., Bull. Jard. Bot. Buitenzorg, ser. 3, 3: 92. 1921; Ridl., Fl. Malay Penins. 2: 628. 1923; P'ei, Mem. Sci. Soc. China 2(3): 144. 1932; Dop in Lecomte, Fl. Indo-Chine 4(7): 864. 1935; H.R. Fletcher, Bull. Misc. Inform., Kew 1938: 429. 1938; Back. & Bakh.f., Fl. Java 2: 609. 1965; Burkill, Dict. Econ. Prod. Malay Penins. 1: 593. 1966; Congdon, Nat. Hist. Bull. Siam Soc. 30(2): 185. 1982; Hsiao, Fl. Taiwan: 423. 1978; Kochummen in Ng, Tree Fl. Mal. 3: 304. 1978; Moldenke & A.L. Moldenke in Dassan. & Fosberg, Rev. Handb. Fl. Ceyl. 4: 417. 1983; Keng, Con. Fl. Singapore: 193. 1990; Hô, Cây cỏ Việt Nam 2: 1055. 1993; Chen & M.G. Gilbert in Wu & Raven, Fl. China 17: 36. 1994; A. Rajendran & P. Daniel, Ind. Verbenaceae: 128. 2002; Phuong in N.T. Ban et al., Fl. Vietnam 3: 293. 2005. *Volkameria angulata* Lour., Fl. Cochinch: 389. 1790. (Leeratiwong. et al 2011)

Figure 3

Figure 3a: *Clerodendrum paniculatum* at the forest verge on the strict nature reserve (3b). Forest plantation roadside where *Clerodendrum paniculatum* were found. Figure 3c: The stout stem, node once borne leaf scar