Biological invasion by *Cenchrus ciliaris* L.: is there an impact on Caatinga composition and diversity of herbaceous stratum?

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Abstract: *Cenchrus ciliaris* is native to South Asia and West Africa, considered one of the main invasive exotic species of Caatinga. This study aims to evaluate the effects caused by *C. ciliaris* on the composition, structure and diversity of Caatinga herbaceous stratum. The study area was divided into five environments, in each were allocated 10 plots measuring 1m x 1m, in which five with sites invaded for *C. ciliaris* and five in places non-invaded. At each sampling unit the number of individuals, the coverage and biomass of each species were known. The evaluated elements were density, frequency, dominance, besides to the diversity and environment similarity. For the sampling were selected 12 families, 16 genus, 19 species and 778 individuals. In general, this invasive exotic showed high coverage and density values, even with the presence of other native species, thus demonstrating the aggressiveness of *C. ciliaris*. All environments showed significant differences in terms of diversity, when compared to the conditions of invaded and non-invaded. The dissimilarity analysis demonstrated the consistent group's formation between invaded and non-invaded conditions. This study showed the *C. ciliaris* ability to change environments, affecting the richness and biodiversity.

Keywords: Bioinvasion, buffel grass, Savannah Steppe.

Invasão biológica por *Cenchrus ciliaris* L.: há impacto sobre a composição e diversidade do estrato herbáceo da Caatinga?

Resumo: *Cenchrus ciliaris* é originária do sul da Ásia e oeste da África, considerada uma das principais espécies exóticas invasoras da Caatinga. O objetivo deste estudo foi avaliar os efeitos causados pela *C. ciliaris* sobre a composição, estrutura e diversidade do estrato herbáceo da Caatinga. A área de estudo foi dividida em cinco ambientes, em cada ambiente foram alocadas 10 parcelas com dimensão de 1m x 1m, das quais cinco em sítios invadidos por *C. ciliaris* e cinco em sítios não invadidos. Em cada unidade amostral foi determinado o número de indivíduos, a cobertura e a biomassa de cada espécie. Também foram avaliadas a densidade, a frequência, a dominância, além da diversidade e similaridade dos ambientes. Foram amostradas 12 famílias, 16 gêneros, 19 espécies e 778 indivíduos. A exótica invasora apresentou elevados valores de cobertura e densidade, mesmo com a presença de outras espécies nativas, demonstrando assim a agressividade da *C. ciliaris*. Todos os ambientes apresentaram diferenças significativas em termos de diversidade, quando comparadas às condições invadida e não invadida. A análise de dissimilaridade revelou a formação de grupos consistentes entre a condição invadida e não invadida. *C. ciliaris* demonstrou a capacidade de modificar os ambientes, comprometendo a riqueza e a biodiversidade.

Palavras-chave: Bioinvasão, capim-buffel, Savana-Estépica.

Introduction

Cenchrus ciliaris L. (buffel grass) is a native grass from South Asia and West Africa (Humphreys, 1967), occurring particularly in Afghanistan, Angola, Egypt, Ethiopia and India (Marshall et al., 2012). However, the species is now widely distributed worldwide, being considered invasive exotic in several countries such as Australia, USA, Mexico and Brazil (Cox et al., 1988; Marshall et al., 2012; Pauchard & Shea, 2006).

Considered to be a "wonder crop", buffel grass has been widely used to better pastoral industries (Marshall et al., 2012). According to Hanselka (1988), in 1917, United States became the first American continent country to use it as fodder, and posteriorly propagated in Mexico and countries from South America (Cox et al., 1988; Williams & Baruch, 2000), where, *C. ciliaris* currently disperses spontaneously (Ibarra et al., 1995).

In 1953, *C. ciliaris* was introduced in São Paulo state, Brazil, and then was spread in the Northeast due to its tolerance to adverse weather conditions (Oliveira, 1993). With the SUPERINTENDÊNCIA DE DESENVOLVIMENTO DO NORDESTE (SUDENE) support, thousands of hectares were planted facing the pasture production in the 1960s (Lira et al., 2004).

It is considered a high economic value species due to its use as fodder (Marshall et al., 2012; Souza & Espíndola, 2000), so, most farmers do not recognize the impacts that *C. ciliaris* may cause (Marshall et al., 2011). The species has high invasiveness occasioning direct impacts on biodiversity, changing the environment and the composition of native species (Buffelgrass Strategic Plan, 2008; Clarke et al., 2005; Friedel et al., 2011).

Morphological and ecological features of this species allow their success to adapt into a new environment (Buffelgrass Strategic Plan, 2008). Part of its versatility comes from its reproduction by apomixis (Bray, 1978; Hussey et al., 1991), forming new seeds with no fecundation (Ferri et al., 1981), thus the pollinator presence is unnecessary and habitat colonization can be made by a single individual.

Currently, *C. ciliaris* is considered one of the main invasive exotics species of Caatinga and unlike most of the species that invade exclusively anthropogenic environments, *C. ciliaris* also disperses and occupies preserved Caatinga sites (Fabricante & Siqueira Filho, 2012a) increasing its importance to the region. According to Clarke et al. (2005), buffel grass has the ability to modify the long term semi-arid ecosystems and the impact caused the herbaceous species is more significant than variations of the rainy season.

Bearing in mind the invasiveness of *C. ciliaris*, aims to evaluate the effects caused by this invasive exotic over Caatinga composition, herbaceous diversity, and structure.

Materials and methods

The study was conducted in Petrolina, PE (9º19'34,30"S and 40 ° 32'55,70" W, average altitude of 376 m). The local vegetation is the Savannah Steppe (Caatinga) (IBGE, 1992) and the climate is the Bsh (hot semiarid region) according to the classification of Koppen-Geiger, with seven to eight dry months, annual rainfall of 612 mm and an average temperature of 26.3 °C (Leal et al., 2003). The predominant soils are Eutrophic red-yellow Latosol.

The study area was divided into five environments, namely: Environment 1 - Caatinga preserved environments; Environment 2 - Caatinga degraded environments; Environment 3 - border of roads and trails; Environment 4 - agricultural environments(elephant grass planting area with irrigation); Environment 5 - ruderal environments. In each environment were placed 10 plots measuring 1m x 1m, in which five with sites invaded for *C. ciliaris* and five in places non-invaded arranged closest to the foregoing.

At each sampling unit, the number of individuals, the coverage and biomass of each species were known. The coverage was acquired through the subplots computation occupied by each taxon. Therefore, the sampling units were divided into 100 sub-units measuring 10 cm x 10 cm. To obtain the biomass, the species individuals in each sample unit were collected and packed separately in paper bags. This material went to drying in a forced circulation oven at 55 ± 5 °C and weighed on an electronic precision scale (Souza et al., 2011).

The evaluated elements were density, frequency and dominance (Müller-Dombois & Ellemberg, 1974), the dry matter (Ribeiro et al. 2014) and the importance value for each species, this last one obtained by the sum of species density, frequency and dominance (Müller-Dombois & Ellemberg, 1974). They were analyzed in factorial arrangement (5 x 2), five environments (environments 1, 2, 3, 4 and 5) and two conditions (invaded and non-invaded sites) with five pseudo--replicas for each treatment.

The environment and site diversities were estimated using the Shannon-Weaver diversity index (H ‘) (Shannon & Weaver, 1949), and the equability through Pielou index (E) (Pielou, 1977). Differences between the diversities were verified by t test ($p \leq 0.05$) (Lehmann, 1997).

To assess the similarity between the flora at environments and sites was used Jaccard coefficient (Sj) (Müller-Dombois & Ellemberg, 1974) and the dissimilarity was verified by Euclidean distance (Ludwig & Reynolds, 1986). The adjustment degree evaluation of the formed groups in the analysis was verified by cophenetic correlation coefficient (Sokal & Rohlf, 1962), and the grouping validity was determined by the ANOSIM permutation test (oneway) (Clarke, 1993).

Results and discussion

For the sampling were selected 12 families, 16 genus, 19 species and 778 individuals. Two species were identified only by genus and another at family level. The non-invaded sites showed 623 individuals, distributed into 11 families, 15 genus and 19 species, while the sites invaded by invasive exotic sampled 155 individuals belonging to six families, seven genus and seven species (Tab. 1).

Tab. 1. Individuals number per species, where: (A1) Caatinga preserved environments; (A2) Caatinga degraded environments; (A3) Borders of roads and trails; (A4) Agricultural environments; (A5) Ruderal environments.

Family	Species	Sites invaded					Sites non-invaded			
		A1	A2	A3	A4	A5	A1	A2	A3	A4
Amaranthaceae	*Gomphrena sp.*	-	-	-	-	-	-	17	15	9
Asteraceae	Sp. indet.	-	-	-	-	-	-	-	-	-
	Centratherum punctatum Cass.	-	-	-	-	-	-	-	-	-
Convolvulaceae	*Ipomoea asarifolia* (Desr.) Roem. &Schult	-	-	-	-	-	-	-	-	-
Euphorbiaceae	*Jatropha mollissima* (Pohl) Baill	2	-	-	-	-	1	-	-	-
Fabaceae	*Desmanthus pernambucanus* (L.) Thell.	6	-	-	-	-	15	-	-	-
	Macroptilium sp.	-	-	-	-	-	-	-	-	-
	Mimosa candolei R.Grether	-	-	-	-	-	-	-	-	4
	Mimosa tenuiflora (Willd.) Poir	-	-	-	-	-	-	-	2	-
Lamiaceae	*Rhaphio donechinus* Schauer	-	-	-	-	-	-	-	2	10
Malvaceae	*Herissantia crispa* (L.) Brizicky	-	-	-	-	-	-	-	3	2
	Pavonia humifusa A.St.-Hil	-	-	-	-	-	-	-	-	-
	*Sida galheirensis*Ulbr	2	-	-	-	1	1	-	-	7
	Waltheria americana L.	-	-	-	-	-	-	23	44	-
	Waltheria rotundifolia Schrank	-	9	-	-	-	-	-	8	35
Molluginaceae	*Mollugo verticillata* L.	7	-	-	-	-	103	-	-	-
Poaceae	*Cenchrus ciliaris* L.	13	17	23	26	9	-	-	-	-
Portulacacea	*Portulaca elatior* Mart	40	-	-	-	-	84	-	14	-
Rubiaceae	*Diodella teres* (Walter) Small	-	-	-	-	-	-		55	-
Turneraceae	*Piriqueta duarteana* (Cambess.) Urb	-	-	-	-	-	-	-	-	-

The Malvaceae and Fabaceae families were those with the highest species richness, confirming the results from other studies in the Caatinga (Reis et al., 2006; Silva et al., 2012; Silva et al., 2013). The Fabaceae family is considered the most diverse Caatinga, probably by the long period of diversification in hot and dry environments and floristic stability of these areas (Souza et al., 2015).

At the invaded sites, the species with the highest importance value (VI) was *C. ciliaris* due to its high density values, presence in all sample units and large coverage (Tab. 2). In a similar study of exotic species in Australia, *C. ciliaris* was considered the most abundant taxon in all treatments (Fairfax & Fensham, 2000).

Table 2 - Structural parameters of the sampled species. In which: DRA = relative density; RR = relative frequency; CR = relative coverage; VI = Importance Value; CI= Invaded Preserved; CNI = Non-invaded Preserved; DI= Caatinga Invaded Degraded; DNI- Caatinga non-invaded Degraded; EI = Invaded borders of roads and trails; ENI= Non-invaded borders of roads and trails; AI- Invaded Agricultural; ANI= Non-invaded Agricultural; RI- Invaded Ruderal; RNI- Non- invaded Ruderal and (-) means absent.

	DR									
Espécies	CI	CNI	EI	ENI	RI	RNI	DI	DNI	AI	ANI
Asteraceae	-	-	-	-	-	4,55	-	-	-	1,47
Cenchrus ciliaris L.	21,7	-	100	-	90	-	65,4	-	100	-
Centratherum punctatum Cass.	-	-	-	-	-	2,27	-	-	-	-
Desmanthus pernambucanus (L.) Thell.	10	6,52	-	-	-	-	-	-	-	-
Diodella teres (Walter) Small	-	-	-	35,3	-	65,9	-	73,7	-	-
Gomphrena sp.	-	-	-	9,62	-	-	-	11,2	-	13,2
Herissantia crispa (L.) Brizicky	-	-	-	1,92	-	-	-	-	-	2,94
Ipomoea asarifolia (Desr.) Roem. & Schult	-	-	-	6,41	-	-	-	-	-	-
Jatropha mollissima (Pohl) Baill	3,33	0,43	-	-	-	-	-	-	-	-
Macroptilum sp.	-	-	-	1,92	-	-	-	-	-	-
Mimosa candollei R.Grether	-	-	-	-	-	-	-	-	-	5,88
Mimosa tenuiflora (Willd.) Poir	-	-	-	1,28	-	-	-	-	-	-
Mollugo verticillata L.	11,7	56,1	-	-	-	-	-	-	-	-
Pavonia humifusa A.St.-Hil	-	-	-	-	-	2,27	-	-	-	-
Piriqueta duarteana (Cambess.) Urb	-	-	-	-	-	13,6	-	-	-	-
Portulaca elatior Mart	50	36,5	-	8,97	-	-	-	-	-	-
Rhaphiodon echinus Schauer	-	-	-	1,28	-	6,82	-	-	-	14,7
Sida galheirensis Ulbr	3,33	0,43	-	-	10	4,55	-	-	-	10,3
Waltheria americana L.	-	-	-	28,2	-	-	-	15,1	-	-
Waltheria rotundifolia Schrank	-	-	-	5,13	-	-	34,6	-	-	51,5
Nativas (soma)	78,3	100	0	100	10	100	34,6	100	0	100

	FR									
Espécies	CI	CNI	EI	ENI	RI	RNI	DI	DNI	AI	ANI
Asteraceae	-	-	-	-	-	16,7	-	-	-	7,69
Cenchrus ciliaris L.	25	-	100	-	83	-	52,1	-	100	-
Centratherum punctatum Cass.	-	-	-	-	-	8,33	-	-	-	-
Desmanthus pernambucanus (L.) Thell.	15	25	-	-	-	-	37,5	-	-	-
Diodella teres (Walter) Small	-	-	-	26	-	16,7	-	40	-	-
Gomphrena sp.	-	-	-	5,3	-	-	-	30	-	23,1
Herissantia crispa (L.) Brizicky	-	-	-	11	-	-	-	-	-	7,69
Ipomoea asarifolia (Desr.) Roem. & Schult	-	-	-	5,3	-	-	-	-	-	-
Jatropha mollissima (Pohl) Baill	10	6,3	-	-	-	-	-	-	-	-
Macroptilum sp.	-	-	-	5,3	-	-	-	-	-	-
Mimosa candollei R.Grether	-	-	-	-	-	-	-	-	-	15,4
Mimosa tenuiflora (Willd.) Poir	-	-	-	5,3	-	-	-	-	-	-
Mollugo verticillata L.	15	31	-	-	-	-	-	-	-	-
Pavonia humifusa A.St.-Hil	-	-	-	-	-	8,33	-	-	-	-
Piriqueta duarteana (Cambess.) Urb	-	-	-	-	-	16,7	-	-	-	-
Portulaca elatior Mart	25	31	-	5,3	-	-	-	-	-	-
Rhaphiodon echinus Schauer	-	-	-	5,3	-	25	-	-	-	7,69
Sida galheirensis Ulbr	10	6,3	-	-	17	8,33	-	-	-	7,69
Waltheria americana L.	-	-	-	21	-	-	-	30	-	-
Waltheria rotundifolia Schrank	-	-	-	11	-	-	10,4	-	-	30,8
Nativas (soma)	75	100	0	100	17	100	47,9	100	0	100

	CR									
Espécies	CI	CNI	EI	ENI	RI	RNI	DI	DNI	AI	ANI
Asteraceae	-	-	-	-	-	7,11	-	-	-	0,31
Cenchrus ciliaris L.	68	-	100	-	95	-	94,7	-	100	-
Centratherum punctatum Cass.	-	-	-	-	-	8,29	-	-	-	-
Desmanthus pernambucanus (L.) Thell.	3,6	5,36	-	-	-	-	-	-	-	-
Diodella teres (Walter) Small	-	-	-	23,1	-	14,9	-	56,8	-	-
Gomphrena sp.	-	-	-	9,91	-	-	-	23,1	-	22
Herissantia crispa (L.) Brizicky	-	-	-	4,01	-	-	-	-	-	2,79
Ipomoea asarifolia (Desr.) Roem. & Schult	-	-	-	7,08	-	-	-	-	-	-
Jatropha mollissima (Pohl) Baill	2,8	0,22	-	-	-	-	-	-	-	-
Macroptilum sp.	-	-	-	3,54	-	-	-	-	-	-
Mimosa candollei R.Grether	-	-	-	-	-	-	-	-	-	10,8
Mimosa tenuiflora (Willd.) Poir	-	-	-	1,42	-	-	-	-	-	-
Mollugo verticillata L.	9,6	51,3	-	-	-	-	-	-	-	-
Pavonia humifusa A.St.-Hil	-	-	-	-	-	14,5	-	-	-	-
Piriqueta duarteana (Cambess.) Urb	-	-	-	-	-	16,6	-	-	-	-
Portulaca elatior Mart	11	40,4	-	3,54	-	-	-	-	-	-
Rhaphiodon echinus Schauer	-	-	-	14,2	-	30,6	-	-	-	13
Sida galheirensis Ulbr	4,4	2,68	-	-	5	8,06	-	-	-	9,91
Waltheria americana L.	-	-	-	28,1	-	-	-	20,1	-	-
Waltheria rotundifolia Schrank	-	-	-	5,19	-	-	5,35	-	-	41,2
Nativas (soma)	32	100	0	100	5	100	5,35	100	0	100

	%VI									
Espécies	CI	CNI	EI	ENI	RI	RNI	DI	DNI	AI	ANI
Asteraceae	-	-	-	-	-	13,9	-	-	-	6,03
Cenchrus ciliaris L.	33,4	-	100	-	87,7	-	64	-	100	-
Centratherum punctatum Cass.	-	-	-	-	-	8,16	-	-	-	-
Desmanthus pernambucanus (L.) Thell.	12,7	19,3	-	-	-	-	26,5	-	-	-
Diodella teres (Walter) Small	-	-	-	26,3	-	17,5	-	46,8	-	-
Gomphrena sp.	-	-	-	6,33	-	-	-	26,7	-	22,5
Herissantia crispa (L.) Brizicky	-	-	-	8,87	-	-	-	-	-	6,56
Ipomoea asarifolia (Desr.) Roem. & Schult	-	-	-	5,65	-	-	-	-	-	-
Jatropha mollissima (Pohl) Baill	8,44	4,48	-	-	-	-	-	-	-	-
Macroptilum sp.	-	-	-	4,76	-	-	-	-	-	-
Mimosa candollei R.Grether	-	-	-	-	-	-	-	-	-	14,1
Mimosa tenuiflora (Willd.) Poir	-	-	-	4,35	-	-	-	-	-	-
Mollugo verticillata L.	13,9	37,7	-	-	-	-	-	-	-	-
Pavonia humifusa A.St.-Hil	-	-	-	-	-	9,72	-	-	-	-
Piriqueta duarteana (Cambess.) Urb	-	-	-	-	-	16,6	-	-	-	-
Portulaca elatior Mart	22,9	33,6	-	5,2	-	-	-	-	-	-
Rhaphiodon echinus Schauer	-	-	-	6,53	-	25,9	-	-	-	8,99
Sida galheirensis Ulbr	8,75	4,96	-	-	12,3	8,16	-	-	-	8,22
Waltheria americana L.	-	-	-	22,7	-	-	-	26,6	-	-
Waltheria rotundifolia Schrank	-	-	-	9,27	-	-	9,49	-	-	33,6
Nativas (soma)	66,6	100	0	100	12,3	100	36	100	0	100

In general, the invasive exotic presented high coverage and density values. However, the environment 4 (agricultural environments) had higher values than the others, with 80.4% coverage and density of 5.2 ind. m², probably because it is a place with constant irrigation and rich in nutrients. The other environments also showed high values, as the environment 3 (borders of roads and trails) had 79.6% coverage and density of 4.6 ind. m², followed by Environment 2 (Caatinga degraded environments) with 70.8% coverage and density of 3.4 ind. m². The lower coverage rates were observed in the environments 1 (Caatinga preserved environments) and 5 (ruderal environments), which received 68.2% coverage and density equal to 2.6 and 1.8 ind. m², respectively.

At the invaded sites were also observed other species such as *Portulaca elatior* Mart with 11.4% coverage and density of 6 ind. m², *Waltheria rotundifolia* Schrank 4% coverage and 1.8 ind. m² density and *Desmanthus pernambucanus* (L.) Thell. with 13.6% coverage and density of 1 ind. m². These were the most representative species, however, they showed lower values compared to the invasive exotic, whether of coverage and/or density. These results may refer to interspecific competition of a dominant species in relation to other species (Jakelaitis et al., 2003). The low density, frequency and dominance of native plants in invaded sites confirm aggressiveness observed for *C. ciliaris* in the field and studies comparing the structure of ecosystems with its presence (Arriaga et al., 2004; Jackson, 2005).

In southern Arizona, *C. ciliaris* is already considered a major threat to the Saguaro cactus, an icon for that region. Its faster spread and ability to promote fires are the main faced problems; water competition and soil shading weaken the plants and prevents native seeds to germinate (Buffel Grass Strategic Plan, 2008), due to the allelopathic effect that contributes to the standardization of vegetation and reduction in productivity of many plants in natural and agroecosystem (Hussain et al., 2011).

Drought tolerance is related to your metabolism that allows for greater efficiency in water use, a feature that facilitates their establishment and one of the reasons for use as fodder (Williams & Baruch, 2000). The ecophysiological characteristics facilitate their wide distribution, since they are able to germinate in a wide temperature range (10 a 40ºC), as well as having a seed engagement structure that reduces germination by 16% which favors the formation and persistence of a soil seed bank (Tinoco-Ojanguren et al., 2016).

When comparing the environments each other, invaded and non-invaded conditions, those without the invasive exotic presence showed differences in terms of diversity (Tab. 3). Comparing the values of the Shannon index (H ‘) to road and agricultural invaded environments was observed predominance of *C. ciliaris* (H = 0), while non-invaded condition to the same environments, diversity values were larger among areas (H ‘= 1.758) and (H’ = 1.402), respectively.

Tab. 3. Shannon-Weaver diversity (H ’) and Pielou equability (E) of sampled plots at different Caatinga environments. In which: CI= Invaded Preserved; CNI = Non-invaded Preserved; DI= Caatinga Invaded Degraded; DNI- Caatinga non-invaded Degraded; EI = Invaded borders of roads and trails; ENI= Non-invaded borders of roads and trails; AI- Invaded Agricultural; ANI= Non-invaded Agricultural; RI- Invaded Ruderal; RNI- Non- invaded Ruderal.

Environments /sites	H´	E
CI	1,276	0,7124
CNI	0,9545	0,593
EI	0	0
ENI	1,758	0,7636
RI	0,3251	0,469
RNI	1,183	0,6077
DI	0,645	0,9306
DNI	0,7558	0,6879
AI	0	0
ANI	1,402	0,7824

This characteristic is common to invasive species that are known for their ability to homogenize the fauna and flora, as well as changing the invaded ecosystem functioning (Mooney & Hobbs, 2000). Studies with *C. ciliaris* corroborate this statement, since the species is able to change the temperature and soil erosion rates, the supply of resources to other species, affecting the diversity (D'antonio & Vitousek, 1992; Flanders, et al. 2006). Its invasion also affects species and ecosystems in arid regions such as Australia, United Stated and South America (Marshall et al., 2012).

This behavior could also be observed for the equability values (J) showing more homogeneous distribution between sites non-invaded. However, the Caatinga preserved environment to both conditions has the same species in the floristic composition (*Desmanthus pernambucanus* (L.) Thell., *Jatropha mollissima* (Pohl) Baill, *Mollugo verticillata* L., *Portulaca elatior* Mart, *Sida galheirensis* Ulbr) including *C. ciliaris* only at invaded condition. This result explains a greater diversity at invaded condition (N'= 1, 276) compared to non-invaded condition (H '= 0, 9545), since the invasive exotic counts as one more species. In this case, the value shown by the t-test for Caatinga preserved environment was not significant (t = 2.44; p = 0.02) (Tab. 4).

Tab. 4. Values calculated by t-test and its significance for different environments. In which: CI= Invaded Preserved; CNI = Non-invaded Preserved; DI= Caatinga Invaded Degraded; DNI- Caatinga non-invaded Degraded; EI = Invaded borders of roads and trails; ENI= Non-invaded borders of roads and trails; AI- Invaded Agricultural; ANI= Non-invaded Agricultural; RI- Invaded Ruderal; RNI- Non- invaded Ruderal.

	CI	CNI	EI	ENI	RI	RNI	DI	DNI	AI	ANI
CI	-	t=2.44; p=0.02	t=11.06; p<0.001	t=-3.64; p=0.00	t=3.91; p=0.00	t=0.61; p=0.54	t=4.74; p=7.53	t=3.84; p=0.00	t=11.06; p=5.22	t=-0.80; p=0.42
CNI		-	t=20.41; p<0.001	t=-9.02; p=3.39	t=2.08; p=0.01	t=-0.94; p=0.35	t=3.96; p=0.00	t=2.53; p=0.01	t=20.41; p<0.01	t=-3.64; p=0.00
EI			-	t=-23.50; p<0.01	t=-1.25; p=0.24	t=-6.39; p=8.90	t=-9.59; p<0.01	t=-12.12; p=4.29	t=N/A; p=N/A	t=-12.90; p<0.01
ENI				-	t=6.26; p<0.01	t=3.25; p=0.00	t=11.22; p<0.01	t=10.20; p<0.01	t=23.50; p<0.01	t=2.83; p=0.01
RI					-	t=-2.99; p=0.01	t=-1.53; p=0.15	t=-2.07; p=0.06	t=1.25; p=0.24	t=-4.46; p=0.00
RNI						-	t=2.62; p=0.01	t=1.97; p=0.05	t=6.39; p<0.01	t=-1.23; p=0.22
DI							-	t=-1.37; p=0.17	t=9.59; p<0.01	t=-5.94; p<0.01
DNI								-	t=12.12; p<0.01	t=-5.02; p<0.01
AI									-	t=-12.90; p<0.01
ANI										-

According to the analysis using the Jaccard quotient between the groups of invaded and non--invaded environments, the similarity was lower than 1% and between Caatinga preserved environments non-invaded and invaded it was 83.3% (Fig. 1). This high similarity degree between the Environment 1 conditions (Caatinga preserved environments) was observed in the permutation test ANOSIM (R = 0.0335, p = 0.0001). However, when subjected to the Euclidean distance, there was the formation of more consistent groupings (less dissimilarity) between the invaded environments, thus, the Caatinga preserved environment non-invaded presented the biggest dissimilarity to other environments (Fig. 2).

Fig. 1. Flora similarity dendrogram by presence/absence matrix of the sampled plots using the Jaccard quotient and cophenetic correlation coefficient of 0.954. In which: CI= Invaded Preserved; CNI = Non-invaded Preserved; DI= Caatinga Invaded Degraded; DNI- Caatinga non-invaded Degraded; EI = Invaded borders of roads and trails; ENI= Non--invaded borders of roads and trails; AI- Invaded Agricultural; ANI= Non-invaded Agricultural; RI- Invaded Ruderal; RNI- Non- invaded Ruderal.

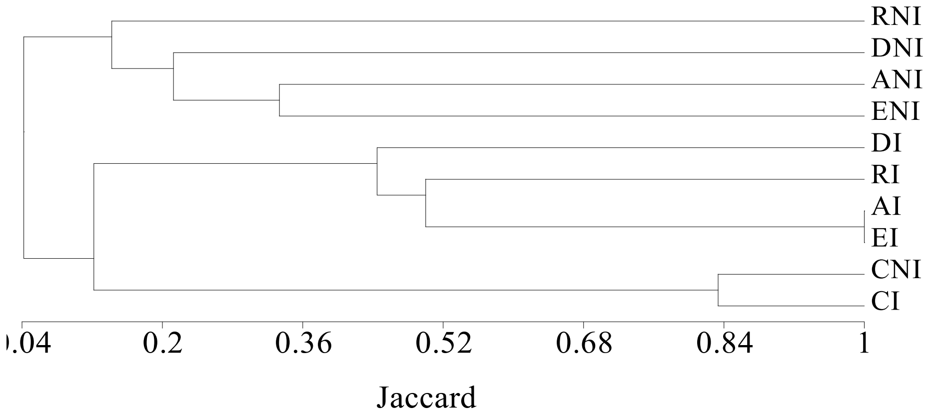
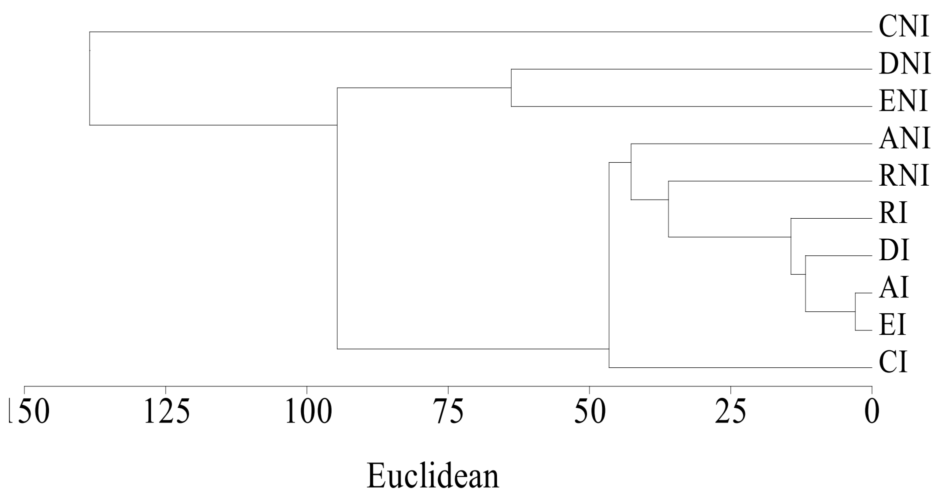


Fig. 2. Flora dissimilarity dendrogram and cophenetic correlation coefficient of 0.946. In which: CI= Invaded Preserved; CNI = Non-invaded Preserved; DI= Caatinga Invaded Degraded; DNI- Caatinga non-invaded Degraded; EI = Invaded borders of roads and trails; ENI= Non-invaded borders of roads and trails; AI- Invaded Agricultural; ANI= Non-invaded Agricultural; RI- Invaded Ruderal; RNI- Non- invaded Ruderal.



The results variation among the analysis of similarity and dissimilarity is due to the last one uses the abundance, and also the species presence or absence, Thus the difference between the invaded and non-invaded sites is observed when taking into account the presence of taxa, as well as the number of individuals that it presents. In a similar study with *Artocarpus heterophyllus* Lam., native from Southeast Asia, it was also observed the same result, the invaded and non-invaded environments showed greater dissimilarity when considering the abundance of species (Fabricante et al., 2012b). This result indicates the existence of *C. ciliaris* effect over the composition of Caatinga native species.

According to Fairfax & Fensham (2000) through studies in Australia evaluating invaded environments by several invasive exotics, among them *C. ciliaris*, *Enteropogon ramosus* and *Eragrostis lacunaria*, realized that the floristic composition of invaded and non-invaded environments differ. Confirming found results, explaining the formation of two well-defined groups that bring together the invaded environments separately from non-invaded environments.

The Caatinga ecosystem is considered area susceptible to invasion by C. ciliaris (Araújo et al., 2013), thus, is essential to seek effective management alternatives, in order to control and mitigate the effects on remaining areas of native biodiversity, particularly the herbaceous stratum that is responsible for a significant portion of the biodiversity of the Caatinga, being more diverse than woody (ARAÚJO et al., 200). The impacts caused by biological invasion are not mitigated the course of time, while management actions are not implemented the invasion will continue to progress.

Conclusion

This study showed the effects caused by *C. ciliaris* on the composition, structure and diversity of Caatinga herbaceous stratum. The invasive exotic species has the ability to set up a negative relationship with the native species, creating dense populations that move away or exclude local species, compromising the herbaceous stratum that represents a significant portion of the biodiversity of Caatinga. Thus, it is necessary the public policies development to forbid the spontaneous dissemination and eradicate the species.

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Recebido em 09.VI.2016
Aceito em 06.X.2016