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Relative contribution of rainfall and coconut hybrids to the abundance and composition of the Auchenorrhyncha community as potential vectors of phytoplasmas in the state of Sergipe, Brazil

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Abstract

1 The quarantine disease Lethal Yellowing (LY) is currently the main threat to coconut cultivation in Brazil. LY is caused by phytoplasmas and is transmitted by *Haplaxius crudus* (Hemiptera: Cixiidae), although other planthoppers/leafhoppers could be involved.

2 We assessed the Auchenorrhyncha community composition on various coconut hybrids, including association with parental and nonparental dwarf coconut accessions.

3 The Auchenorrhyncha were trapped in 2016 between the dry and rainy seasons (March and April), in the rainy season (July and August) and in the dry season (November and December).

4 *Oecleus sergipensis* (Hemiptera: Cixiidae) accounted for 73% of the individuals, with a predominance at the dry-to-rainy season transition. *Curtara samera* (Hemiptera: Cicadellidae) was the best-represented species on the hybrids Brazilian Green Dwarf × Brazilian Tall – Praia do Forte, Brazilian Green Dwarf × Vanuatuan Tall and Malayan Yellow Dwarf × West African Tall. *Oecleus sergipensis* was the best-represented species on the hybrids Malayan Red Dwarf × Tagnanan Tall, Malayan Red Dwarf × Vanuatuan Tall and Malayan Yellow Dwarf × Brazilian Tall – Praia do Forte.

5 Individuals of a species of Cenchreini and *Omolicna nigripennis* (Hemiptera: Derbidae) increase in the rainy season; *Balclutha* sp. (Hemiptera: Cicadellidae) and *Cedusa* sp. (Hemiptera: Derbidae) are prevalent in the transition period between the dry and rainy seasons. Knowledge about potential Auchenorrhyncha phytoplasma vectors on coconut hybrids could contribute to the development of strategies for use in breeding programmes for coconut LY prevention.

Keywords Cixiidae, *Cocos nucifera*, hybrids, lethal yellowing, *Oecleus sergipensis*.

Introduction

Lethal Yellowing syndromes of coconut are highly devastating diseases, affecting coconut cultivation and 38 palm species worldwide. They are caused by phytoplasmas. In Florida, Central America and the Caribbean, phytoplasmas of the group 16S rIV are responsible for the declines in local lethal palm. The most prevalent form is known as 'Lethal Yellowing' (LY) (Harrison *et al.*, 2002; Harrison *et al.*, 2008). No efficient curative control methods for these diseases are known and, within 3–6 months after the appearance of the first symptoms, all attacked plants die, causing the complete destruction of the plantation (McCoy *et al.*, 1983).

Lethal palm declines also occur in some countries of North and Central America, Africa, Caribbean and Oceania (Dollet *et al.*, 2009; Harrison *et al.*, 2014; Gurr *et al.*, 2016). They are quarantine diseases that still remain undetected in Brazil. Nevertheless, they pose a serious threat to Brazilian coconut cultivation because the country is the fourth largest producer of

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coconut worldwide and the top producer of coconut water (FAO, 2017). Aside from dwarf and tall coconut varieties, dwarf × tall coconut hybrids also are widely cultivated for their commercial utility in the production of copra/oil, fibres and coconut water (Siqueira *et al.*, 2002).

Species of auchenorrhynchous Hemiptera are vectors of phytoplasmas associated with diseases in crops of high economic value, such as corn, grapes, fruit trees and vegetables. This has promoted the targeted investigation of Fulgoroidea (e.g. Cixiidae and Derbidae; 'planthoppers') and deltocephaline Cicadellidae ('leafhoppers') as potential plant pathogen vectors. These planthoppers and leafhoppers have a feeding habit restricted to the phloem sap where phytoplasmas multiply, characterizing them as potential vectors of these pathogens (Weintraub & Beanland, 2006). In Florida, the planthopper *Haplaxius crudus* (Van Duzee) (Hemiptera: Cixiidae) is known as a vector of the16S rIV phytoplasmas associated with LY (Howard *et al.*, 1983). Despite several years of research, the vectors of other lethal palm declines in East and West Africa remain unknown (Mpunami *et al.*, 2000; Philippe *et al.*, 2009). Moreover, some of the research has been limited to testing insects for the presence of pathogens (Mpunami *et al.*, 2000). A positive insect confirms that it has fed on an infected plant, although it says nothing about that the ability of the insect to transmit the pathogens to a healthy plant.

The dynamics of an insect community are influenced by the abiotic and biotic factors that comprise the environmental conditions. The main factors responsible for changes in population numbers, which can contribute significantly to an increase or decrease in the number of individuals, are rainfall, temperature and relative humidity (Win *et al.*, 2011).

Accordingly, the present study aimed to survey and analyze the Auchenorrhyncha community composition of potential phytoplasma vectors of LY in dwarf × tall coconut hybrids, including parent accessions of dwarf and nonparent coconut, in different seasons in Brazil.

Materials and methods

Sampling site

Auchenorrhyncha were collected from six dwarf × tall coconut hybrids in the transition between dry and rainy seasons (March: 70 mm rain, 30 °C; April: 56 mm rain, 29 °C); rainy season (July: 75 mm rain, 29.7 °C; August: 52 mm rain 29.8 °C); and in the dry season (November: 0 mm rain 33 °C; December: 0 mm rain, 32.3 °C) of 2016 in an experimental field (−10.54352, −36.62632) of Embrapa Tabuleiros Costeiros in the municipality of Itaporanga D'Ajuda, located in the northeastern Brazilian state of Sergipe. The climate of Itaporanga D'Ajuda is tropical rainy with dry summers, in accordance with Köppen's classification (Peel *et al.*, 2007). The mean monthly rainfall and temperature of the study period were measured at a meteorological station installed in the experimental area, and field data were provided by the Brazilian Center for Weather Forecasting and Climate Studies, respectively.

Coconut varieties and hybrids

The coconut hybrids evaluated were: BGD × BRT (Brazilian Green Dwarf × Brazilian Tall – Praia do Forte); MYD × BRT (Malayan Yellow Dwarf × Brazilian Tall – Praia do Forte); BGD × VTT (Brazilian Green Dwarf × Vanuatu Tall); MYD × WAT (Malayan Yellow Dwarf × West African Tall); MRD × VTT (Malayan Red Dwarf × Vanuatu Tall); and MRD × TAG (Malayan Red Dwarf × Tagnanan Tall), which were planted in an area previously used for the evaluation of hybrids of coconut trees from different countries (Batugal *et al.*, 2005). The coconut hybrids were 14 years old, spaced 8.5 × 8.5 m, and arranged in a randomized block design with five replications and 12 hybrid trees per replication. During the samplings period, no cultural practices other than mechanical weeding were employed in the coconut plantation.

Auchenorrhyncha collection

Monthly collections were carried out using double-sided yellow sticky traps (8.5 × 11 cm; ISCA Technologies, Inc., Riverside, California), placed on the leaves of three plants per replication of each coconut hybrid (i.e. 15 traps per hybrid). The traps were collected 15 days after installation in each sampling month, and the Auchenorrhyncha were removed with the help of a solvent (Tira Cola; Allchem Química, Uruguay).

Auchenorrhyncha were identified at the family and subfamily levels, based on morphological characteristics and dichotomous keys (Triplehorn & Johnson, 2011; Grazia *et al.*, 2012). Thereafter, specimens were sent to taxonomic specialists for identification to the lowest possible level (targeting species level), based on specialized technical references for each taxonomic group. Representative specimens were deposited in the Entomological Collection, University of Delaware, Department of Entomology and Wildlife Ecology, Newark, Delaware, U.S.A., and the Department of Zoology, Federal University of Rio de Janeiro, Brazil.

Statistical analysis

Changes in the composition of the Auchenorrhyncha community were modelled by multivariate classification and regression tree analysis (MCRA) (De'ath, 2002), using the total rainfall and mean temperature values of 1, 2 and 3 months prior to the samplings, and the hybrids as explanatory variables. This analysis explains the variation in a multivariate response variable as a function of categorical and quantitative explanatory variables (De'ath, 2002). Based on all data represented by a single node at the top, the tree is amplified by repeated binary partitioning of the response variable data. Each partition is defined by a simple rule, based on a single explanatory variable. The explanatory variable and its respective levels or classes used for each data partition are selected among all available combinations because they result in the smallest sum of squares within the two nodes derived from the partition. The partitioning procedure is continued until the tree is sufficiently large for pruning to an appropriate size (number of end nodes). The tree size for interpretation was determined to ensure the smallest minimum relative error at highest frequency in a series of 20 cross-validations, each repeated 10 times (Breiman *et al.*, 1984; De'ath, 2002). For a new partition, the criterion selected was that each new node to be generated should be based on at least three observations. The tree diagram represents all partitioning rules used to separate the different nodes.

For this analysis, a library of routines in a univariate regression tree (T. Therneau, unpublished data) was extended by the inclusion of additional C routines for the implementation of multivariate regression tree analysis (De'ath, 2002). S-PLUS, version 4.0 (Mathsoft Inc., Cambridge, Massachusetts) was used for the analyses. Prior to the analysis, the count of each species was relativized by the sum of counts of all species within each sample.

Indicator species analysis was used to identify the typical species of each intermediate and terminal node of the MCRA (Dufrêne & Legendre, 1997). The method proposed by these authors calculates an indicator value (IV) for each species, which describes the degree of association of this species to a given condition. In this case, each terminal node of the MCRA was treated as a condition. The indicator value, calculated as the product between the relative abundance (RA) and relative frequency (RF), is assigned to each species and condition evaluated. Relative abundance is expressed as the proportional abundance of a particular species, under a given condition, relative to the abundance of this same species under all evaluated conditions. The relative frequency describes the proportion of samples under a particular condition containing a particular species. The Monte Carlo test, employing 5000 runs with randomized data, was used to test the null hypothesis that the IV obtained with the real data is not greater than that obtained randomly (i.e. that the species has no indicator value). For this analysis, the species counts were processed without relativizing, using PC-ORD 6 (McCune & Mefford, 2011).

Pearson's correlation analysis was performed between individuals of the most abundant Auchenorrhyncha species caught on hybrids and parent and nonparent dwarf coconut accessions, with a total of 12 observations per hybrid group with the same parent dwarf coconut, using an EXCEL spreadsheet (Microsoft Corp., Redmond, Washington). The numbers of auchenorrynchos collected from the parent and nonparent dwarf coconut (i.e. Brazilian Green Dwarf Jequi – BGDJ; Cameroon Red Dwarf – CRD; Malayan Red Dwarf – MRD; Brazilian Red Dwarf Gramame – BRDG; Brazilian Yellow Dwarf Gramame – BYDG; and Malayan Yellow Dwarf – MYD) used in the correlation with the hybrids were obtained in a previous study (Silva *et al.*, 2018), which was carried out in the same seasons as the survey of the Auchenorrhyncha community on hybrid coconuts in the experimental field of Itaporanga D'Ajuda. Parental dwarf coconut means that there is a dwarf parent in the composition of the hybrid, whereas the nonparent dwarf is not related to any of the varieties that make up the hybrid.

Results

Auchenorrhyncha survey

In total, 1153 insects belonging to seven families of Auchenorrhyncha (Cixiidae, Cicadellidae, Derbidae, Membracidae, Delphacidae, Flatidae and Dictyopharidae) were captured on sticky cards places in the six dwarf × tall coconut hybrids. Seven families were represented by 30 Auchenorrhyncha species, of which *Oecleus sergipensis* Bartlett (Cixiidae), *Curtara samera* DeLong & Freytag, *Balclutha* sp. (Cicadellidae), Cenchreini sp., *Omolicna nigripennis* Caldwell, *Cedusa* sp. (Derbidae) and *Erechtia gibbosa* (DeGeer) (Membracidae) were the most abundant, representing 81% of individuals collected (Table 1). Delphacidae, Flatidae and Dictyopharidae were represented only by one individual in each family, respectively.

With respect to seasonality, the highest number of Auchenorrhyncha (272 individuals) was captured in the transition period between the dry and rainy seasons in March, and the lowest number of Auchenorrhyncha was captured in the rainy season in July (56 individuals). With a total of 679 individuals, *O. sergipensis* was the most abundant species in the present study, accounting for 73% of the collected Auchenorrhyncha. The lowest number of individuals of this species was counted in July (fiindividuals) and the highest in March (214 individuals), in the dry-to-rainy season transition.

Regarding the impact of coconut varieties and hybrids, the highest number of Auchenorrhyncha (219 individuals) was captured on hybrid BGD × BRT, and the lowest number (105 individuals) on MYD × WAT. The same pattern was found for *O. sergipensis* (Table 1). This pattern was driven by the occurrence of *O. sergipensis*.

The multivariate regression and classification model generated a tree with five terminal nodes, explaining 77% of the data variability for the Auchenorrhyncha community composition, of which 69% was explained by cumulative bimonthly precipitation (Bp) prior to samplings and 8% by coconut hybrids (Fig. 1).

Two distinct communities were observed in samplings with Bp < 52 mm and Bp between 52 mm and 119.87 mm, with no differentiation among the hybrids. Species indicator analysis indicated *E. gibbosa*, with an indicator value of 27 ($P = 0.325$), as the only typical species when Bp < 52 mm (Table 2). At Bp between 52 and 119 mm, the typical species were *C. samera* (IV = 71, $P = 0.008$), *Balclutha* sp. (IV = 67, $P = 0.001$) and *Cedusa* sp. (IV = 67, $P = 0.001$). *Erechtia gibbosa* was observed only in the dry season (relative abundance = 100%, relative frequency = 33% at Bp < 52 mm). *Cedusa* sp. and *Balclutha* sp. occurred exclusively at Bp between 52 and 119 mm (RA = 100%, RR = 67% at 52 mm < Bp < 119 mm). *Curtara samera* relative abundance was 77% and relative frequency 92% at 52 mm < Bp < 119 mm.

At Bp > 119 mm, the Auchenorrhyncha community composition of the hybrids BGD × BRT, BGD × VTT and MYD × WAT differed from those of MRD × TAG, MRD × VTT and MYD × BRT. A comparison of these two groups indicated *C. samera* as the only typical species (IV = 76, $P < 0.069$) of the first group, and *O. sergipensis* as a typical species of the second group (IV = 94, $P = 0.014$). In their respective hybrid groups, both species were recorded in all observations (RF = 100%). Some 76% of individuals of *C. samera* and 94% of *O. sergipensis* occurred in their respective preferred hybrid group (Table 2).

The Auchenorrhyncha community composition of the hybrid group BGD × BRT, BGD × VTT and MYD × WAT did not differ under different Bp. However, in the hybrid group MRD × TAG, MRD × VTT and MYD × BRT, two relatively distinct communities were observed as a result of variations in Bp. *Curtara samera* occurred exclusively and in all observations of periods with Bp > 182 mm. The same was observed for *Balclutha* sp. in periods with Bp between 119 and 182 mm. It was found that the two MYD hybrids differed from each other for this composition. On MYD × BRT, an enriched composition of *O. sergipensis* was observed grouped with hybrids derived from MRD, whereas

Table 1 Total number of individuals of the most abundant Auchenorrhyncha species on dwarf × tall coconut hybrids

	Family	Cixiidae	Cicadellidae			Derbidae		Membracidae	
Average rainfall and temperature	Hybrids[a]	*Oecleus sergipensis*	*Curtara samera*	*Balclutha* sp.	Cenchreini sp.	*Omolicna nigripennis*	*Cedusa* sp.	*Erechtia gibbosa*	Total
March (70 mm, 30 °C)	BGD × BRT	46	5	1	0	0	2	0	54
	MYD × BRT	39	4	0	0	0	2	0	45
	BGD × VTT	24	2	0	0	0	5	0	31
	MYD × WAT	30	8	5	0	0	4	0	47
	MRD × VTT	44	1	3	2	1	3	0	54
	MRD × TAG	31	5	3	0	0	2	0	41
April (56 mm, 29 °C)	BGD × BRT	20	7	3	0	0	1	0	31
	MYD × BRT	18	6	0	0	0	0	0	24
	BGD × VTT	7	6	1	0	0	0	0	14
	MYD × WAT	9	0	0	0	0	2	0	11
	MRD × VTT	19	4	1	0	3	0	0	27
	MRD × TAG	9	2	2	0	1	0	0	14
July (75 mm, 29.7 °C)	BGD × BRT	1	9	0	1	1	1	0	13
	MYD × BRT	2	7	0	3	0	2	0	14
	BGD × VTT	0	2	0	0	1	1	0	4
	MYD × WAT	0	2	1	0	1	1	0	5
	MRD × VTT	1	5	0	2	0	0	0	8
	MRD × TAG	1	5	0	3	3	0	0	12
August (52 mm, 29.8 °C)	BGD × BRT	1	16	0	4	4	1	0	26
	MYD × BRT	12	0	1	0	0	0	0	13
	BGD × VTT	0	22	0	3	4	1	0	30
	MYD × WAT	0	3	0	3	0	0	0	6
	MRD × VTT	7	0	1	4	4	1	0	17
	MRD × TAG	7	0	1	4	4	1	0	17
November (0 mm, 33 °C)	BGD × BRT	63	2	0	0	0	0	0	65
	MYD × BRT	23	1	0	0	0	0	0	24
	BGD × VTT	24	0	0	0	0	0	1	25
	MYD × WAT	12	0	0	0	1	0	0	13
	MRD × VTT	35	1	0	0	0	0	0	36
	MRD × TAG	23	0	0	0	0	0	1	24
December (0 mm, 32.3 °C)	BGD × BRT	27	2	0	0	1	0	0	30
	MYD × BRT	42	2	0	0	0	0	0	44
	BGD × VTT	21	4	0	0	0	0	2	27
	MYD × WAT	22	0	0	0	0	0	1	23
	MRD × VTT	29	2	0	0	0	0	4	35
	MRD × TAG	30	1	0	0	0	0	0	31
	Total	679	136	23	29	29	30	9	935

[a]BGD × BRT (Brazilian Green Dwarf × Brazilian Tall - Praia do Forte), MYD × BRT (Malayan Yellow Dwarf × Brazilian Tall - Praia do Forte), BGD × VTT (Brazilian Green Dwarf × Vanuatuan Tall); MYD × WAT (Malayan Yellow Dwarf × West African Tall); MRD × VTT (Malayan Red Dwarf × Vanuatuan Tall); and MRD × TAG (Malayan Red Dwarf × Tagnanan Tall).

MYD × WAT, with the lowest mean abundance of *O. sergipensis*, was grouped with the hybrids derived from BGDJ. For the tall parent coconut, the communities on BRT-derived hybrids were similar, also with more *O. sergipensis* individuals (Table 2).

The temporal correlation of MRD and its hybrids (MRD × VTT and MRD × TAG) with *O. sergipensis* populations was high ($r = 0.74$, $P < 0.01$), in contrast to that observed for BGDJ ($r = 0.39$, $P < 0.10$) and MYD ($r = -0.37$, $P < 0.10$) and their respective hybrids. Correlations between MRD with parental hybrids and the other nonparental dwarf coconut accessions with MYD ($r = -0.40$, $P < 0.05$) and BGDJ ($r = 0.54$; $P < 0.05$) were not significant (Fig. 2).

Discussion

The composition of the Auchenorrhyncha community on different coconut hybrids in the state of Sergipe, Brazil, was influenced mainly by rainfall, followed by the identity of the coconut hybrids. Auchenorrhyncha that are potential phytoplasma vectors of coconut LY were represented by the family Cixiidae, especially *O. sergipensis* as the most abundant, followed by the subfamily Deltocephalinae (Cicadellidae) and possibly the family Derbidae.

Some Auchenorrhyncha species are vectors of phytoplasma causing diseases in agricultural crops and ornamental plants, mainly Cixiidae and Deltocephalinae species (Howard *et al.*, 1983; Weintraub & Beanland, 2006; Bressan *et al.*, 2009; Dakhil *et al.*, 2011; Cvrkovic *et al.*, 2014; Chuche *et al.*, 2016). Also, a derbid species was claimed to be vector of the pathogen that causes Kerala Root Wilt of coconut in India (Edwin & Mohankumar, 2007a; Edwin & Mohankumar, 2007b; Rajan, 2013), in addition to the first recognized vector in the family Tingidae, *Stephanitis typica* (Distant) (Heteroptera, not Auchenorrhynhca) (Mathen *et al.*, 1987; Mathen *et al.*, 1990). Knowledge about

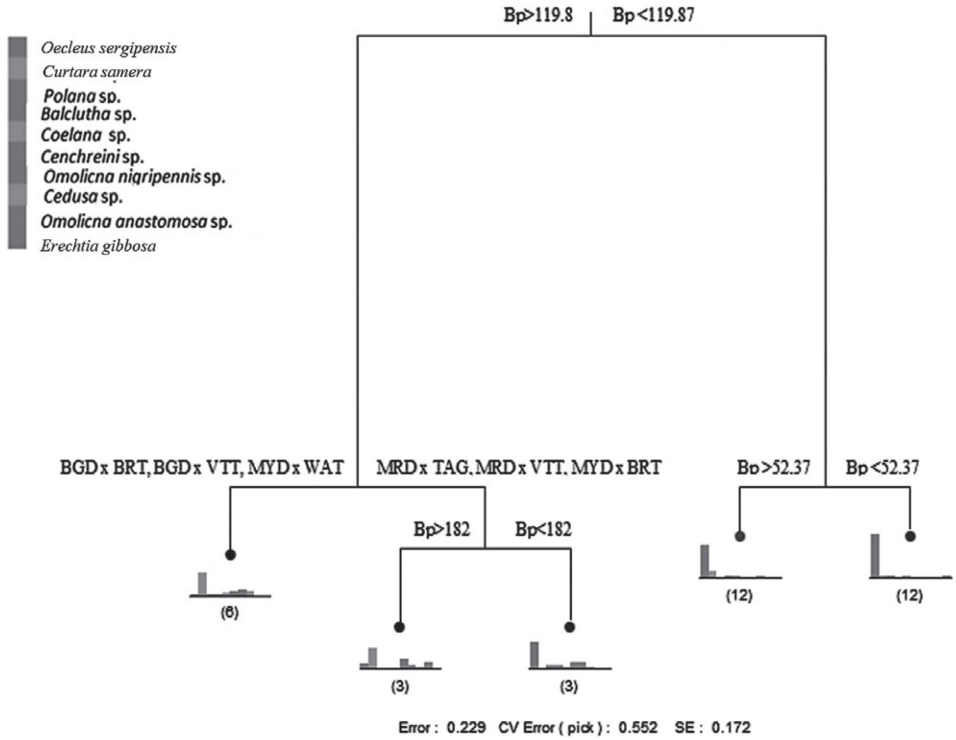

Figure 1 Tree regression model of the Auchenorrhyncha community as affected by bimonthly precipitation (Bp) and coconut hybrids. The length of the vertical tree branches is proportional to the variability explained by the explanatory variables used in each partition.

insect communities is extremely important for risk management of pest introduction and the dispersion and implementation of appropriate site-specific phytosanitary measures (Melo *et al.*, 2008).

The LY vector *H. crudus* (Hemiptera: Fulgoroidea) was found in Brazil in the 1980/90s, in an oil palm plantation in Belem, Para State (Louise, 1990; Celestino Filho *et al.*, 1993). A recent survey in Para in 2017 confirmed the presence of this insect species on oil palms and coconuts in the surroundings of Belem (F. G. Silva, unpublished data). In our studies in Sergipe, no *H. crudus* specimens were found, although a high number of individuals of a new species of cixiid in the genus *Oecleus* Stål, belonging to the same family and tribe as *H. crudus* (Cixiidae: Oecleini), was captured. This new species, *O. sergipensis*, was described recently (Bartlett *et al.*, 2018), and is a potential vector of phytoplasmas, including coconut LY phytoplasmas. *Oecleus* species also are reported from coconut plantations in Mexico. *Oecleus snowi* Ball was suspected as a potential possible vector of LY in a LY-affected coconut plantation of Tabasco State. In this plantation, several cixiids were present: *Haplaxius skarphion* (Kramer), *Haplaxius caldwelli* (Kramer) and *H. crudus*. However all attempts to transmit LY to healthy coconuts in cages with captured *Haplaxius* spp. from this LY affected plantation failed despite several thousands of insects being released in cages with coconuts (J.-L. Dzido, C. F. Ortiz Garcia, C. Oropeza, S. Fabre and M. Dollet, unpublished data). This raised the question of the possible existence of other vectors of LY in the Caribbean and Central America, as already suspected (Dollet *et al.*, 2010).

Among the Deltocephalinae collected in the present study, *Balclutha* spp. are considered as potential vectors of phytoplasmas. Some species of *Balclutha* tested positive for almond witches-broom phytoplasma in Lebanon (Dakhil *et al.*, 2011). Phytoplasmas associated with sugarcane white leaf disease were detected by a polymerase chain reaction (PCR) in two species of *Balclutha* in northeastern Thailand (Hanboonsong *et al.*, 2006) and a new phytoplasma associated with periwinkle leaf yellowing disease in Taiwan was identified by PCR in some *Balclutha* species (Chen *et al.*, 2011). However, no experimental transmission was obtained with these species of leafhoppers. Positive insects show that the individuals fed on an infected plant, although they indicate nothing about the potential to transmit the pathogen.

We collected specimes of the derbid genus *Cedusa* sp. a difficult genus with 16 species recorded from Brazil among 100+ Neotropical species (Flynn & Kramer, 1983; Kramer, 1986). The species found here may be *Cedusa yipara* (Kramer) and/or *Cedusa yowza* (Kramer) because both these species have been found in recent Auchenorrhyncha sampling from palm species in Brazil (F. G. Silva, unpublished data). In Jamaica, *Cedusa* sp. was suspected to be a putative vector of LY (Brown *et al.*, 2006), although no positive transmissions were obtained, only insects positive for the pathogens by molecular analysis. Another derbid belonging to a new genus and species of the tribe Cenchreini was also collected. It is similar to *Omolicna* but differs from that genus both in head and genitalic features. *Omolicna* has been detected on palms and was suggested as a potential vector of phytoplasmas (Segarra-Carmona *et al.*, 2013; Halbert *et al.*, 2014); however, no positive transmissions have been obtained to

Table 2 Indicator analyses of Auchenorrhyncha species collected on coconut hybrids, according to the tree regression model, with bimonthly precipitation and parental dwarf clusters

Comparison among samples groups[a]	Most abundant species	Relative abundance (RA)		Relative frequency (RF)		Indicator value (IV)		Group with significant IV	*P*
Group 1 BGD × BRT; BGD × VTT; MYD × WAT (Bp > 119.9 mm)		Group 1	Group 2	Group 1	Group 2	Group 1	Group 2		
versus	*Oecleus sergipensis*	6	94	33	100	2	94	2	0.014
Group 2 MRD × TAG; MRD × VTT; MYD × BRT (Bp > 119.9 mm)	*Curtara samera*	76	24	100	50	76	12	1	0.069
		Group 3	Group 4	Group 3	Group 4	Group 3	Group 4		
Group 3 (Bp > 182 mm)	*Curtara samera*	100	0	100	0	100	0	3	0.108
versus	*Balclutha* sp.	0	100	0	100	0	100	4	0.108
Group 4 (Bp < 182 mm) (MRD × TAG; MRD × VTT; MYD × BRT)									
		Group 5	Group 6	Group 5	Group 6	Group 5	Group 6		
Group 5 (Bp: 52.37 mm and 119.9 mm)									
versus	*Curtara samera*	77	23	92	67	71	15	5	0.008
Group 6 (Bp < 52.37 mm)	*Balclutha* sp.	100	0	67	0	67	0	5	0.001
	Cedusa sp.	100	0	67	0	67	0	5	0.001
	Erechtia gibbosa	18	82	17	33	3	27	6	0.325

[a]BGD × BRT (Brazilian Green Dwarf × Brazilian Tall - Praia do Forte), MYD × BRT (Malayan Yellow Dwarf × Brazilian Tall - Praia do Forte), BGD × VTT (Brazilian Green Dwarf × Vanuatuan Tall); MYD × WAT (Malayan Yellow Dwarf × West African Tall); MRD × VTT (Malayan Red Dwarf × Vanuatuan Tall); and MRD × TAG (Malayan Red Dwarf × Tagnanan Tall).

date. The derbid *Diostrombus mkurangai* Wilson was suspected of transmission of palm lethal decline in Tanzania because of PCR detection in insects from the field (Mpunami *et al.*, 2000); however, once again, no positive transmissions were recorded.

The Auchenorrhyncha life cycle depends on a complex of factors, such as local humidity, temperature and photoperiod (Lohmann *et al.*, 2010; Koji *et al.*, 2012). The largest numbers of Auchenorrhyncha in the present study were captured in March and April in the dry-to-rainy season transition, corresponding to the period with the highest occurrence of *O. sergipensis* on coconut hybrids. This result is in agreement with another study showing that *O. sergipensis* population peaked on dwarf coconut accessions in Brazil in March and April 2016, indicating this species as being predominant in the dry-to-rainy season transition (Silva *et al.*, 2018).

Among the climatic factors, the rainfall regime is one of the main factors for the distribution of insect populations. Seasonality in precipitation alters the availability of soil water and nutrients, eventually affecting plant development and increasing resources for insects (Araújo, 2013). The rainfall prior to March and April 2016 may have induced an increase in the development of undergrowth vegetation (grasses) between the tree rows and in the vicinity of the coconut hybrids, favouring better conditions for the nutrition of these palms and, consequently, for the Auchenorrhyncha development, mainly of cixiids, which reproduce on grass roots.

Most cixiid nymphs are considered to inhabit grass roots and the adults are mainly associated with coconut and other palm, whereas derbid nymphs feed on wood associated fungi and adults on monocotyledons, supposedly (Triplehorn & Johnson, 2011). Possibly, the appearance of the *O. sergipensis* population in the dry season suggests that the eggs were laid during a humid period, favouring nymphal development and hatching.

Oecleus sergipensis was found on all coconut hybrids, particularly on parental red dwarf hybrids. Interestingly, the Auchenorrhyncha communities on the two MRD-derived hybrids were similar, as observed for the two BGDJ-derived hybrids. It is also noteworthy to see the high correlation of *O. sergipensis* individuals with MRD-derived hybrids. Silva *et al.* (2018) reported that this species was found on coconut accessions in living coconut genebanks, in the state of Sergipe, and captured in larger numbers on red dwarf coconut.

The present study contributes to the knowledge of the composition of the Auchenorrhyncha community found on coconut hybrids during contrasting periods (dry and wet) and this information could help in the establishment of control measures in the event that LY reaches Brazil.

Rainfall followed by coconut hybrids were found to be the factors with a major influence on the composition of the Auchenorrhyncha community. In general, potential vector species of phytoplasmas, *O. sergipensis*, *Balclutha* sp., Cenchreini sp., *O. nigripennis* and *Cedusa* sp. were found on coconut hybrids. The greatest abundance of Auchenorrhyncha was found on hybrid BGD × BRT. *Oecleus sergipensis* was the only species with a high correlation between hybrids derived from the parent Malayan Red Dwarf, whereas the hybrid MYD × WAT provided the lowest abundance of this species. Unfortunately, both the MYD and the WAT are susceptible to LY. MYD was considered as a resistant variety (or at least, less susceptible than the

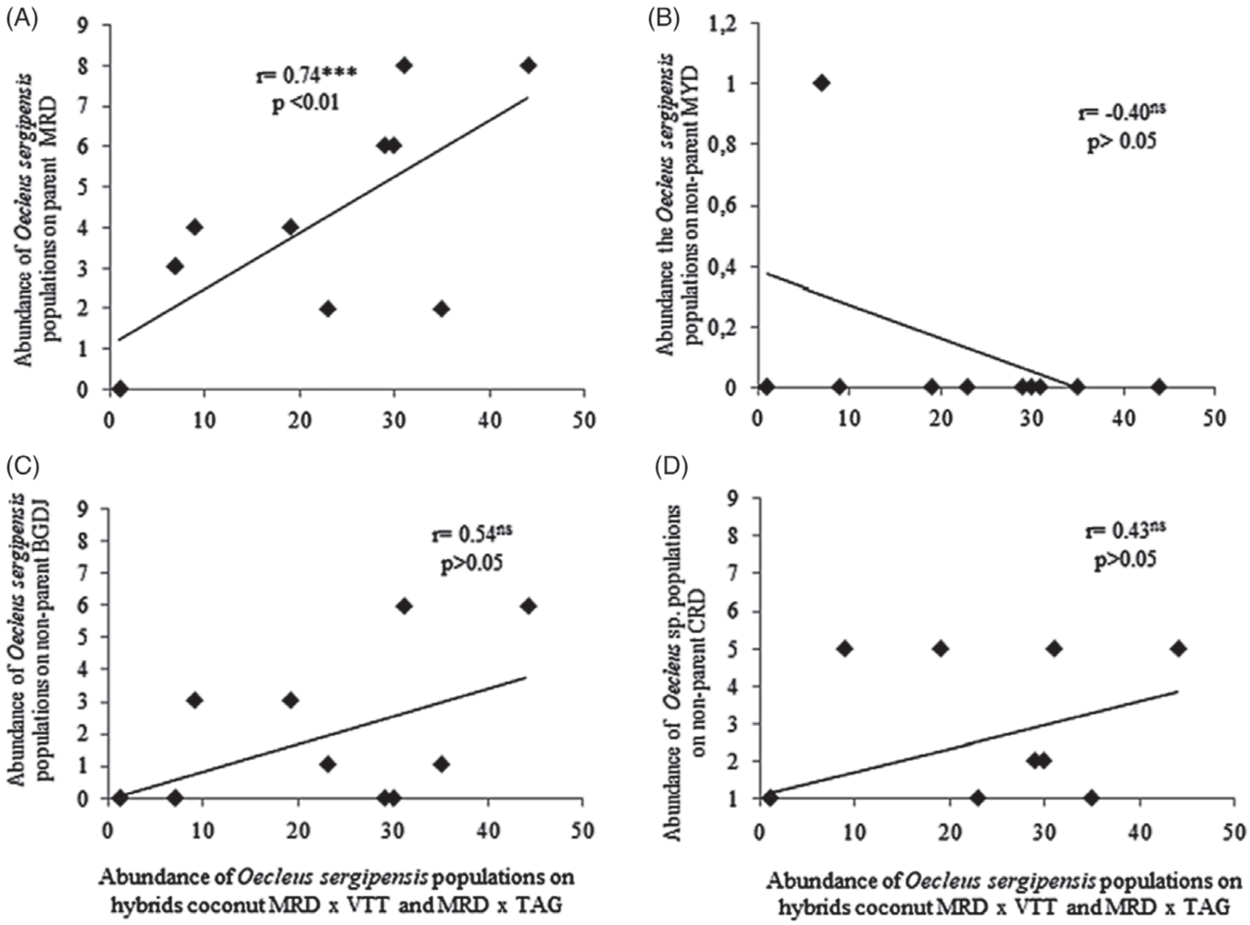

Figure 2 Correlations between *Oecleus sergipensis* abundance on the hybrids MRD × VTT (Malayan red dwarf × Vanuatuan tall) and MRD × TAG (Malayan red dwarf × Tagnanan tall) with parental dwarf MRD (Malayan red) (A) and the nonparental dwarfs MYD (Malayan yellow) (B), BGDJ (Brazilian green) (C) and CRD (Cameroon red) (D). ns, not significant ($P < 0.05$).

others varieties grown in Jamaica) in the 1960/70s, although they were severely affected by LY in Jamaica and Florida in the late 1980s (Broschat *et al.*, 2002; Lebrun *et al.*, 2008). Information on Auchenorryncha communities should be used in breeding programmes for disease prevention and management of LY, in the event that it arrives in Brazil.

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