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Short Communication

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Short Communication

Relative contribution of biotic and abiotic factors to population fluctuations of Auchenorrhyncha community that could play a role in the Cape Saint Paul Wilt Disease (CSPWD) (lethal yellowing) pathosystem in Ghana

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As a major setback to the global coconut industry, lethal yellowing disease (LYD), caused by phytoplasmas, continues to threaten coconut palms in the Americas, the Caribbean, Africa, and Oceania. Despite its economic impacts, limited information exists on LYD vectors, which impedes the prevention and management of the disease. Using double-sided yellow sticky traps, we investigate the factors that influence the seasonal abundance and population dynamics of three sap-sucking insects of LYD, i.e., *Diostrombus* (Hemiptera: Derbidae) sp. and *Patara* sp. (Hemiptera: Derbidae), and *Nedoptepa curta* Dmitriev (Hemiptera: Cicadellidae), on five coconut genotypes (Sri Lanka Green Dwarf (SGD), Vanuatu Tall (VTT), SGD × VTT, Malayan Yellow Dwarf (MYD) × VTT, and West African Tall (WAT)) in the Western Region, and one (SGD) in the Central Region of Ghana from April 2019 to May 2021. The results showed that *N. curta* and *Patara* sp. were the most abundant species in the Western and Central Regions, respectively. There was a significant difference between the coconut cultivars and sap-sucking insects. The peak population development of the sap-sucking insects was recorded during the dry season on all the coconut genotypes at all sampling locations. A significant positive correlation was detected between temperature and the population of *N. curta* and *Patara* sp. In the Agona Nkwanta, VTT had the highest population of *N. curta*, whereas WAT had the highest population of *Patara* sp. and *Diostrombus* sp. These findings provide useful information for assessing the role of factors that could affect the Cape Saint Paul Wilt disease pathosystem.

Key words: abiotic factors, population dynamics, sap-sucking insects, phytoplasma, lethal yellowing

Introduction

Sap-sucking insects from the suborder Auchenorrhyncha are vectors that spread diseases in highly valuable ornamental plants and crops (Silva et al. 2018; Bastos et al. 2019). Some species known as phytoplasma vectors belong to the families Cixiidae, Delphacidae, Cicadellidae, Derbidae, and Flatidae (Pilotti et al. 2014). Phytoplasma is a group of prokaryotic plant pathogens that lack a cell wall and are generally found in the phloem of plants and the salivary glands of their insect vectors (Christensen et al. 2005, Bertaccini and Duduk 2009). Lethal yellowing disease (LYD) associated with phytoplasmas has destroyed several coconuts and other palm trees globally (Arocha-Rosete et al. 2014, Gurr et al. 2016, Myrie et al. 2022). In Ghana, LYD, locally called Cape Saint Paul Wilt disease (CSPWD) has destroyed over 20,000 ha of coconut plantation (Council for Scientific and Industrial Research—Oil Palm Research Institute, Unpublished).

Although many of the insect vectors have not been identified (Gurr et al. 2016), the planthopper *Myndus crudus* (reclassified taxonomically as *Haplaxius crudus* Van Duzee (Cixiidae)) has been reported as the vector of LYD on coconut in Florida (Howard et al. 1983, Howard 2001). In Cote D'Ivoire, a derbid (undescribed species of *Cedusa*), cixiid planthopper, *Oecleus mackaspringii* Stål (Cixiidae) (Brown et al. 2006), *Diostrombus mkurangai* Wilson (Derbidae), *Meenoplus* sp. (Meenoplidae) (Mpunami et al. 2000), *Platacantha lutea* Westwood (Pentatomidae), *Diostrombus mkurangai* Wilson (Derbidae) (Dollet et al. 2011), and *Nedotepa curta* Dmitriev (Cicadellidae) have been identified as potential vectors of LYD (Kwadjo et al. 2018). In the case of CSPWD, *Diostrombus* sp. (Derbidae), *Diostrombus* (undescribed), and *Patara* sp. (Derbidae) tested positive for the presence of this phytoplasma group (Philippe et al. 2009, Yankey et al. 2022). Yet transmission trials with these potential vectors were inconclusive. Positive detection of phytoplasma in insects does not guarantee vector status, but it provides potential agents for screening in biological assays, increasing the likelihood of identifying real vectors.

Nevertheless, there is a limited understanding of the factors influencing the population dynamics of LYD-vectored insects (Arocha-Rosete et al. 2014). Yet, detailed knowledge of the factors affecting their population dynamics is a prerequisite for understanding the CSPWD epidemiology and developing an integrated pest management strategy against the disease. This study therefore investigated the factors that influence the population fluctuations of three sap-sucking insects, namely, *Diostrombus* species (Fig. 1A) and *Patara* species (Fig. 1B) (Yankey et al. 2022) and *N. curta* (Fig. 1C) (Kwadjo et al. (2018) in two major coconut-growing regions of Ghana.

Materials and Methods

Study Site

The study was conducted at two research stations of the Council for Scientific and Industrial Research—Oil Palm Research Institute at Asebu in the Central Region and Agona Nkwanta in the Western Region of Ghana from May 2019 to April 2021 (Table 1; Fig. 2).

Sampling of Sap-Sucking Insects

Sampling of the insects was carried out once every 2 weeks for 2 years using yellow sticky traps made from 30 × 30 cm plywood, yellow-painted, and coated with insect adhesive Tanglefoot Tangle-Trap (Tanglefoot Company Grand Rapids, MI49504, USA). Five coconut genotypes, SGD (dwarf), SGD × VTT (hybrid), MYD × VTT (hybrid), VTT (tall), and WAT (tall) were selected at Agona Nkwanta (Table 1), with four palms per genotype selected at 40 m distance to avoid trap interference. At Asebu, one genotype, SGD, was selected due to the absence of the other genotype (Table 1) and this genotype was selected at the same distance as at Agona Nkwanta. At both locations, each genotype was replicated four times, and a yellow sticky trap was hung on each selected palm canopy at a height of 20 m using a twine that formed a pulley system and tied to the lower part of the palm trunk and on the frond. Traps were removed and replaced on each sampling date. Trapped insects were collected using a camel hairbrush and stored in bottles with 70% ethanol for laboratory sorting, counting, and identification in the laboratory. Total number of insects collected were 21,871 and 298 at Agona Nkwanta and Asebu, respectively. Identification keys of Dietrich (2005), Szwedo (2005), and Dollet et al. (2020) were used as identification guides and voucher specimens were preserved at the Coconut Research Program Collection of Insects and Other Arthropods, Sekondi, Ghana.

Abiotic Factors Recording

Temperature and relative humidity data were taken using HOBO UX120-006M 4-Channel Analog Data Logger, while rainfall records were obtained from the nearest meteorological station (< 3 km from the study site).

Fig. 1. Sap-sucking insects used in this study A) *Diostrombus* sp., B) *Patara* sp., and C) *Nedotepa curta*.

Table 1. Background information on the coconut plantations selected for the study in Central and Western Regions, Ghana.

Region	Station	Genotype	Age (yrs)	Number of trees	Size (acre)	Geographic coordinates	Altitude (m)
Western	Agona Nkwanta	Sri Lankan Green Dwarf (SGD)	9	360	5	4°54′42.376″ N, 1°58′25.762″ W	48
		Sri Lankan Green Dwarf × Venuatu Tall (SGD × VTT)	25	160	2		
		Malayan Yellow Dwarf × Venuatu Tall (MYD × VTT)	13	160	2		
		Venuatu Tall (VTT)	10	90	1		
		West Africa Tall (WAT)	9	60	1		
Central	Asebu	Sri Lankan Green Dwarf (SGD)	15	63	0.5	5°12′39.794″ N, 1°13′42.79″ W	64

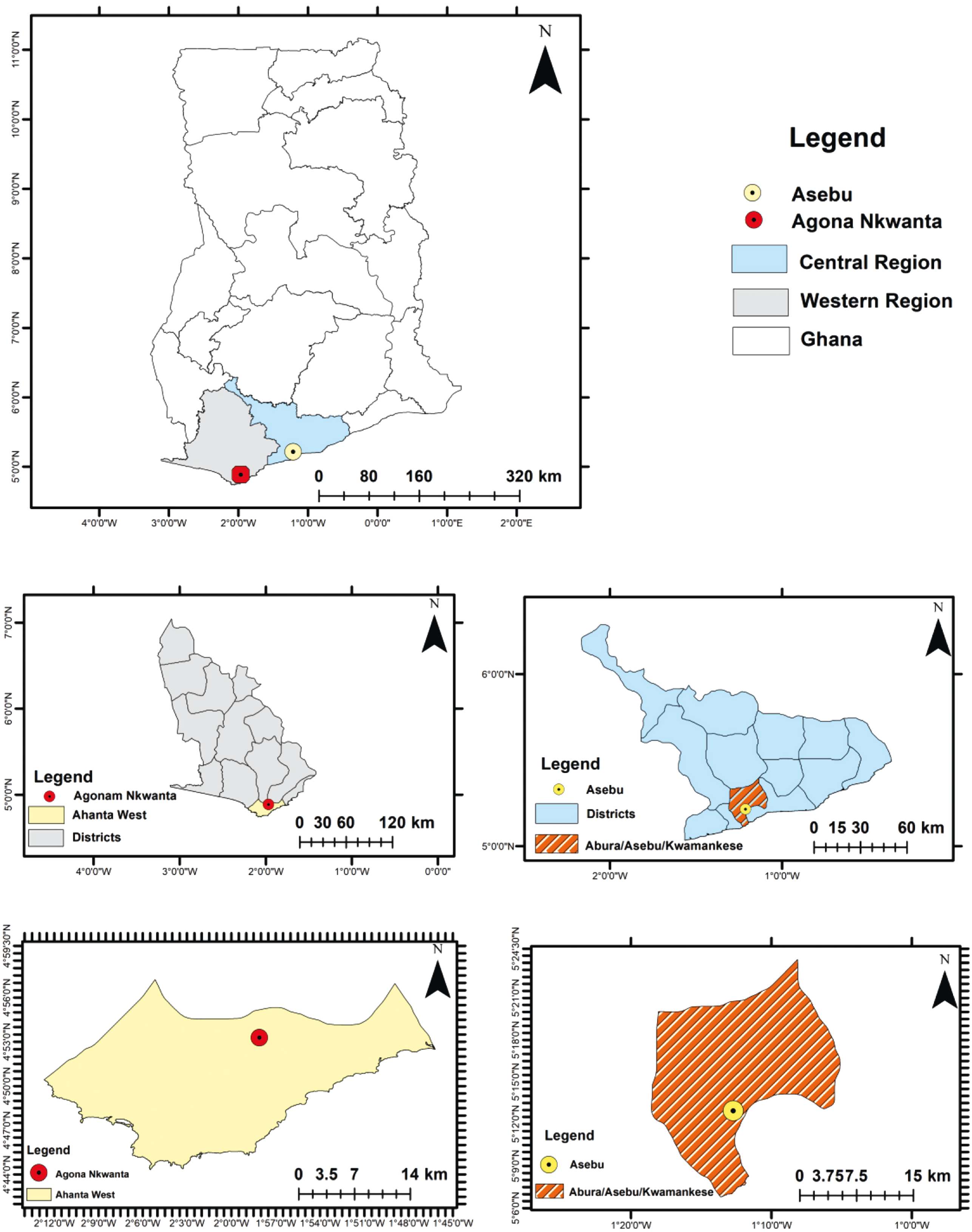

Fig. 2. Map showing the study sites, Agona Nkwanta in the Western region and Asebu in the Central region of Ghana.

Data Analysis

Insect numbers were collated by months, palm genotype, and location for 2 years (May 2019 to April 2021). We used a repeated measures analysis of variance to: (i) assess the effect of the coconut genotypes on insect catches across the study period, and (ii) determine the effects of time (sampling date) on the insect

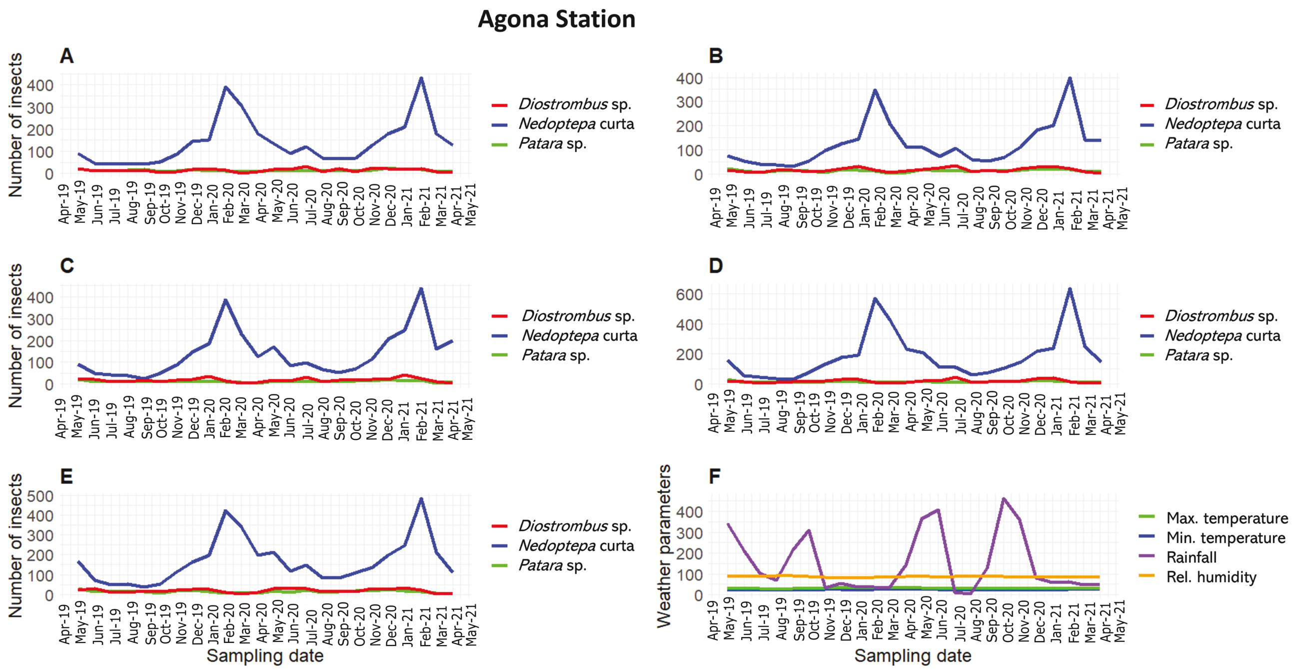

Fig. 3. Population fluctuation of the number of the different insects at different sampling dates on A) SGD, B) SDG × VTT, C) MYD × VTT, D) VTT, E) WAT, and F) abiotic parameters on the different sampling dates at Agona station. Where (SGD = Sri Lankan Green Dwarf, VTT = Vanuatu Tall, MYD = Malayan Yellow Dwarf, and WAT = West African Tall).

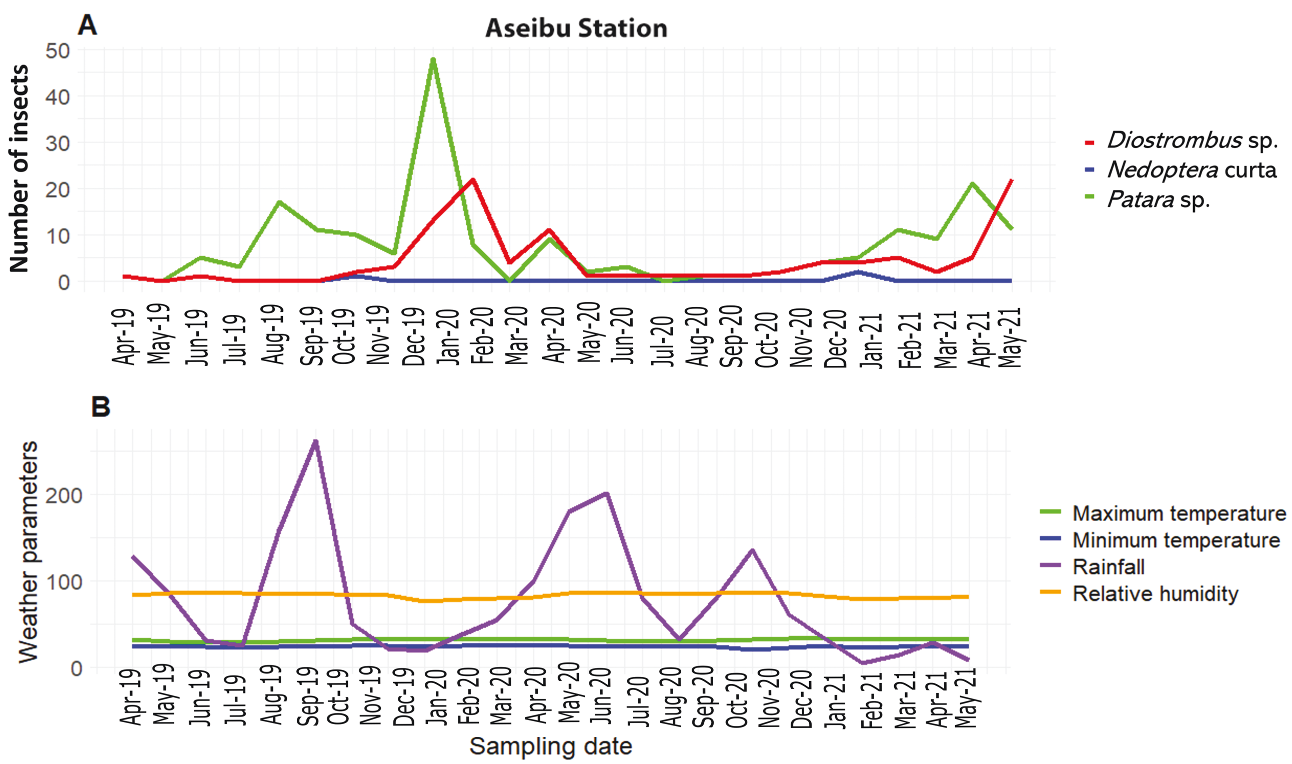

Fig. 4. Population fluctuation of the number of the different insects at different sampling dates on A) SDG and B) abiotic parameters on the different sampling dates at Asebu station. Where (SGD = Sri Lankan Green Dwarf).

catches on each of the coconut genotypes across the study period. The data were analyzed using R packages lmerTest (Kuznetsova et al. 2017) and ez (Lawrence 2016). A chord diagram was used to depict the contribution of genotypes and sampling dates on the insects collected over the sampling period by installing the package circlize (Gu et al. 2014). To analyze the relationship between the weather parameters and the insect catches, we used Spearman rank correlation. All analyses were performed using R software (version 4.3.1) (R Core Team 2020) at 95% confidence interval.

Results

Seasonal Variation in Population Densities of Sap-Sucking Insects

At Agona Nkwanta, *N. curta* had a peak population during the dry season (January to March) when rainfall was at the minimum (Fig. 3) and minor peaks for *Patara* sp. and *Diostrombus* sp., during the study period on all genotypes. At Asebu, there were multiple peaks during the sampling period, *Patara* sp. population peaked in January when the rainfall was at a minimum, whereas *Diostrombus* sp. had multiple peaks with a noticeable peak in February. In contrast, *N. curta* had no noticeable peaks during the sampling period at Asebu (Fig. 4).

The population of the sap-sucking insects was influenced by the abiotic factors assessed during the study (Table 2, Supplementary Fig. S1). At Agona Nkwanta, maximum and minimum temperatures had a significant positive correlation on *N. curta* abundance, while a significant negative relationship was found between *N. curta* and relative humidity (Table 2). In contrast, no significant correlation occurred between rainfall and the sap-sucking insects. The population of *Patara* sp. was negatively significant and increased with a decrease in relative humidity ($R = -0.52$, $P = 0.009$). *Diostrombus* sp. had a significant negative correlation with maximum temperature and relative humidity, whereas *N. curta* significantly and negatively correlated with relative humidity (Table 2) at Asebu.

Contribution of Coconut Genotype on Sap-Sucking Insects

At Agona Nkwanta, the population of *N. curta* was highest on the five coconut genotypes (SGD, VTT, SGD × VTT, MYD × VTT, and WAT), followed by *Diostrombus* sp. and then *Patara* sp. (Fig. 5). The population densities of *Patara* sp. were highest at Asebu, followed by *Diostrombus* sp., and then *N. curta* (Table 3).

The chord diagram showed the contribution of sampling dates on insects' abundance (Fig. 6). In Agona Nkwanta, high number of *N. curta* were sampled in February of 2020 and 2021. High number of *Patara* sp. were sampled in December 2020 on SGD, SGD × VTT, and MYD × VTT genotypes and in May 2019 on VTT and WAT genotypes (Fig. 6). High number of *Diostrombus* sp. were sampled in January 2021 on MYD × VTT and WAT, and in July 2020 on SGD × VTT and VTT (Fig. 6). Similarly, at Asebu, high number of *Patara* sp. were sampled in January 2020 while more adult *Diostrombus* sp. were sampled in February 2020 and April 2021. Several *N. curta* were sampled only in November 2019 and December 2020.

Discussion

This study documented the population dynamics of three sap-sucking insects of CSPWD for 2 years in the Central and Western Regions of Ghana with *N. curta* and *Patara* sp. being the dominant species in the Western and Central Regions of Ghana, respectively. This study indicated that at Agona Nkwanta, VTT and WAT had the highest population, and SGD × VTT and MYD × VTT had the lowest population of *N. curta*, and *Patara* sp., respectively. A similar study by Yawson and Dery (2004), reported a relatively higher number of *Nzinga palmivora* (reclassified taxonomically as *N. curta*) on WAT palms in the Western Region of Ghana. Previous studies showed that tall

Table 2. Correlation between the genotype, sap-sucking insects, and climatic variables

Location	Genotype	Vectors	Minimum temperature		Maximum temperature		Rainfall		Relative humidity	
			P-value	rho	*P*-value	rho	*P*-value	rho	*P*-value	rho
Agona Nkwanta	SGD	*N. curta*	**<0.001**	0.69	**<0.001**	0.77	0.08	−0.36	**0.001**	−0.63
		Patara sp.	0.36	−0.19	0.49	−0.15	0.59	0.12	0.49	0.15
		Diostrombus sp.	0.52	−0.14	0.49	−0.15	0.53	0.14	0.73	0.073
	SGD × VTT	*N. curta*	**<0.001**	0.69	**<0.001**	0.81	**0.046**	−0.41	**<0.001**	−0.72
		Patara sp.	0.75	0.07	0.6	0.11	0.48	0.15	0.81	−0.053
		Diostrombus sp.	0.72	−0.077	0.83	0.046	0.76	0.066	0.7	−0.084
	MYD × VTT	*N. curta*	**<0.001**	0.73	**<0.001**	0.82	0.078	−0.37	**<0.001**	−0.67
		Patara sp.	0.63	−0.1	0.62	−0.11	0.12	0.33	0.45	0.16
		Diostrombus sp.	0.32	−0.21	0.92	−0.022	0.69	0.084	0.8	−0.056
	VTT	*N. curta*	**<0.001**	0.76	**<0.001**	0.8	0.2	−0.27	**0.002**	−0.59
		Patara sp.	0.8	0.055	0.62	0.11	0.39	0.19	0.9	−0.028
		Diostrombu sp.	0.38	−0.19	0.95	−0.013	0.58	0.12	0.64	−0.1
	WAT	*N. curta*	**<0.001**	0.7	**<0.001**	0.72	0.2	−0.27	**0.011**	−0.51
		Patara sp.	0.32	−0.21	0.48	−0.15	0.36	0.2	0.5	0.15
		Diostrombus sp.	0.42	−0.17	0.66	−0.094	0.15	0.3	0.86	0.037
Asebu	SGD	*N. curta*	0.44	0.17	0.97	−0.009	0.92	−0.022	**<0.001**	−0.74
		Patara sp.	0.3	−0.22	0.13	0.32	0.083	−0.36	**0.0091**	−0.52
		Diostrombus sp.	0.34	0.2	**<0.001**	0.84	0.92	−0.022	**<0.001**	−0.74

ecotypes especially WAT are more susceptible to CSPWD than the dwarf and hybrid (Harrison et al. 2002, Dery et al. 2008). However, Silva et al. (2018), reported high Auchenorrhyncha abundance in Brazil's dwarf coconut genotypes. In this study, *N. curta* was more abundant which could potentially impact the CSPWD pathosystem.

High temperature and low humidity prevailing during the dry season (February) at Agona Nkwanta likely created a favorable ecological condition for the population buildup of *N. curta*. However, on all the genotypes at both sampling locations, the studied insects peaked in the dry season except for *Diostrombus* sp. whose peak populations occur during the major rainy season on VTT. Silva et al. (2018) also showed that Auchenorrhyncha population buildup in March and April (transition from dry to rainy season) and August (transition from rainy to dry season). Likewise, Koji et al. (2012) reported that *Maiestas banda* (Kramer), a vector of phytoplasma in Napier grass in Kenya had a peak population at the end of the minor rainy season (October–December) in 2007. The significant correlation between the population of *N. curta* at Agona Nkwanta and *Patara* sp. with temperature will help in developing a predictive model, for early detection and timely control measures. It is also desirable that the population of sap-sucking insects be controlled to reduce disease pressure as demonstrated by Nkansah-Poku et al. (2005). The findings in this study highlight the critical periods during which insect populations reach their peak. Understanding these peak periods enables agricultural and environmental managers to make more informed decisions, leading to more effective and sustainable control practices. The insights gained from this study demonstrate that knowledge of the insects' peak population periods can be instrumental in disease management. This can be achieved by implementing strategies to reduce populations, such as mating disruption, utilizing host resistance, applying chemical controls, inducing plant defense mechanisms, and adopting integrated pest management techniques. These approaches have been validated by other studies, including those by Sisterson (2009), Bragard et al. (2013), Vacas et al. (2015), Wari et al. (2019), and Farina et al. (2019).

Table 3. Abundance of sap-sucking insects collected on the different genotypes in the two sites

Location/Genotype	*Nedoptepa curta*	*Patara* sp.	*Diostrombus* sp.
Agona Nkwanta station (total)	18,149	1629	2093
MYD × VTT	3,373 (18.7%)	306 (18.8%)	446 (21.3%)
SGD	3,379 (18.6%)	335 (20.6%)	363 (17.3%)
SGD × VTT	2,961 (16.3%)	311 (19.1%)	387 (18.5%)
VTT	4,429 (24.4%)	329 (20.2%)	436 (20.8%)
WAT	4,007 (22.1%)	348 (21.4%)	461 (22.0%)
Asebu station (total)	5	188	106
SGD	5 (100.0%)	188 (100%)	106 (100%)

The seasonal variations were mainly explained by abiotic factors. When the temperature rises, the population of *N. curta* on all the genotypes at Agona Nkwanta increases like a study carried out by Bastos et al. (2019), which shows a significant positive correlation between *H. crudus* population and temperature. This study reveals no significant correlation between rainfall and sap-sucking insects at Agona Nkwanta, while Bastos et al. (2019) found a negative correlation with the *H. crudus* population in Brazil. This study reveals that temperature and relative humidity are important abiotic factors that impact the population fluctuations of sap-sucking insects. These findings corroborate the observations of Umar et al. (2003) and Bishnol et al. (1996) who reported that leafhopper population is directly proportional to temperature. However, Paradell et al. (2014)

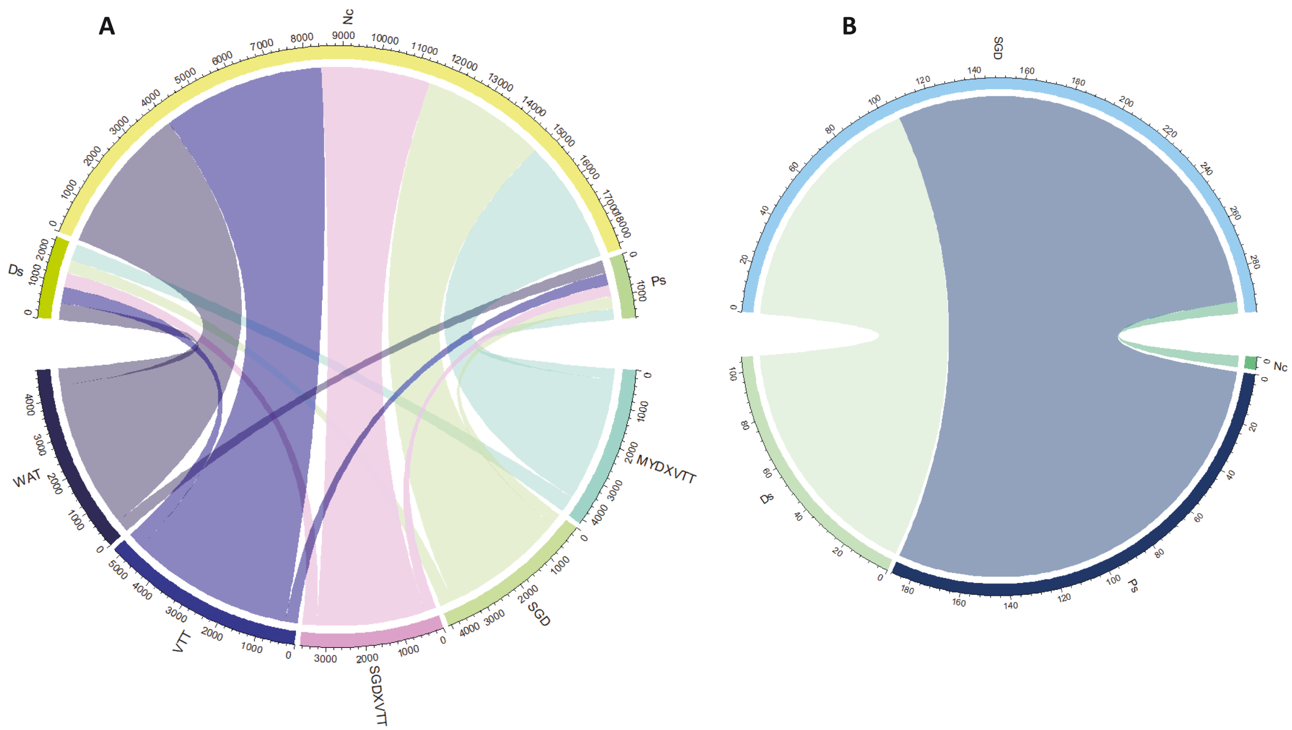

Fig. 5. Chord diagram indicating the contribution of variety toward the total number of adults on different genotypes at (A) Agona Nkwanta, (B) Asebu. Where (SGD = Sri Lankan Green Dwarf, VTT = Vanuatu Tall, MYD = Malayan Yellow Dwarf, and WAT = West African Tall). Note*: NC = *N. curta*, DS = *Diostrombus* sp., and Ps = *Patara* sp.

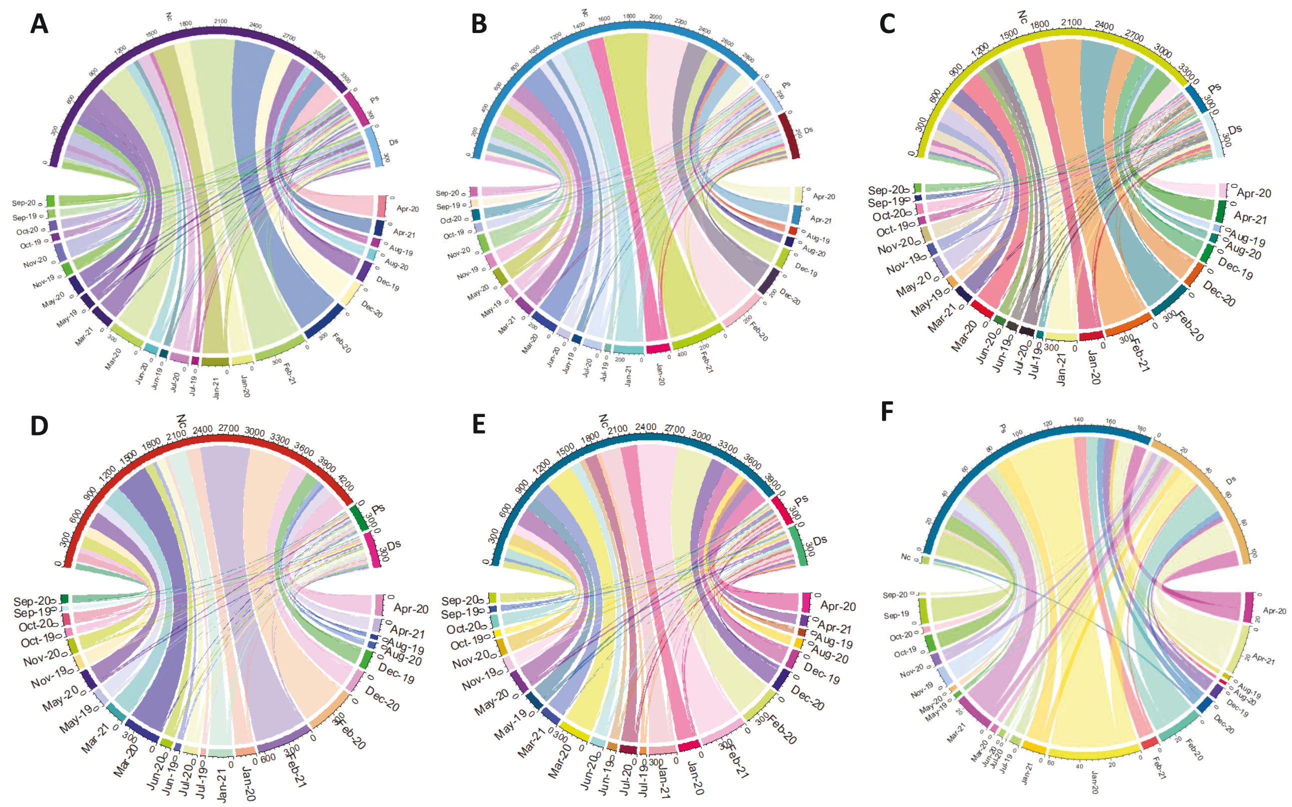

Fig. 6. Chord diagram indicating the contribution of sampling date toward the total number of adults on different genotype at different stations. A) SGD at Agona Nkwanta Station, B) SGD × VTT at Agona Nkwanta Station, C) MYD × VTT at Agona Nkwanta Station, D) VTT at Agona Nkwanta Station, E) WAT at Agona Nkwanta Station, and F) SGD at Asebu Station, where (SGD = Sri Lankan Green Dwarf, VTT = Vanuatu Tall, MYD = Malayan Yellow Dwarf, and WAT = West African Tall). Note*: NC = *N. curta*, DS = *Diostrombus* sp., and Ps = *Patara* sp.

reported that the population of *H. crudus* increases when temperature, air humidity, and photoperiod simultaneously increase. This shows that abiotic factors affect the population dynamics of insect pests and non-pests (Rahmathulla et al. 2012).

The sap-sucking insect population is highly seasonal, with peak periods varying based on sampling dates, genotypes, and locations. Adult catches varied dramatically between sampling dates, ranging from zero individuals (*N. curta* at Asebu) to a maximum of 159 individuals (*N. curta* at Agona Nkwanta). The study found that *N. curta* population densities peak in February, consistent with an earlier study in Ghana (Yawson and Dery 2004) indicating the peak period for *N. curta* population is January to February. At Asebu, more adult *Patara* sp. were collected in January 2020 while more adult *Diostrombus* sp. were collected in February 2020 and April 2021. This may be associated with the adaptation of the different putative vectors to the coconut genotype.

Further research on sap-sucking insects in other coconut-growing regions in Ghana is needed for a better understanding of the biology and ecology of CSPWD potential vectors. Finally, this study provides baseline information for understanding the bioecology of sap-sucking insects likely to vectored CSPWD in Ghana and paved the way for the establishment of an integrated approach for effective control of the disease.

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Author contributions

Elizabeth Tettey (Conceptualization [equal], Data curation [lead], Formal analysis [equal], Funding acquisition [supporting], Investigation, Methodology [equal], Project administration [supporting], Resources [equal], Software [supporting], Supervision, Validation, Visualization [equal], Writing—original draft, Writing—review & editing [lead]), Owusu Fordjour Aidoo (Conceptualization [equal], Data curation, Formal analysis [lead], Funding acquisition [supporting], Investigation, Methodology [equal], Project administration, Resources, Software [supporting], Supervision, Validation, Visualization [equal], Writing—original draft [supporting], Writing—review & editing [equal]), Isaac Ativor (Conceptualization [lead], Data curation [supporting], Formal analysis [equal], Funding acquisition [supporting], Investigation [equal], Methodology [lead], Project administration, Resources, Software [supporting], Supervision [lead], Validation, Visualization [supporting], Writing—original draft, Writing—review & editing [equal]), and Egya Yankey (Conceptualization [lead], Data curation, Formal analysis [supporting], Funding acquisition [lead], Investigation, Methodology [supporting], Project administration [lead], Resources [equal], Software [supporting], Supervision [lead], Validation, Visualization, Writing—original draft [supporting], Writing—review & editing [equal])

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Supplementary Data

Supplementary data are available at *Journal of Economic Entomology* online.

Data Availability

The data for the study are available upon request from the corresponding author.

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