Andalasian International Journal of Entomology - Vol. 2 No. 2 (2024) 88-97 http://aijent.lppm.unand.ac.id

Original Research

AIJENT OPEN ACCESS

Assessing Cashew Orchards Management Practices and Infestation rates of *Apate terebrans* in Orchards in Burkina Faso, West Africa

SOMDA Naamwin Irkoum Zephirin[1] and UGWU Juliana Amaka[2]*

[1]*Pan African University Life and Earth Sciences Institute (including Health and Agriculture), Ibadan, Nigeria*
[2]*Federal College of Forestry, Forestry Research Institute of Nigeria, Ibadan, Nigeria*

Article history

Received : August 14, 2024
Revised : September 22, 2024
Accepted : October 24, 2024
Published : October 30, 2024

***Correspondence**

SOMDA Naamwin Irkoum Zephirin
E-mail: somdazephirin610@gmail.com

License and copyright

Copyright: © 2024 by the authors. **Open-access** publication under the terms and conditions of the **Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA)** license

E-ISSN and DOI

E-ISSN: 3026-2461
10.25077/aijent.2.2.88-97.2024

ABSTRACT

Cashew is a significant export crop in Burkina Faso but suffers substantial damage from the cashew wood borer *Apate terebrans* Pallas. Despite its economic importance, the population dynamics of this beetle have not previously been studied in Burkina Faso, limiting the development of effective control strategies. This study monitored infestation patterns on 960 cashew trees randomly selected from 8 localities in 4 regions across two agro-ecological zones. The trees were inspected monthly over two consecutive years according to typical producer management practices. As *A. terebrans* bores inside branches and trunks, direct observation of adults was unfeasible. Therefore, infestation rates were estimated by counting fresh entry holes monthly. Over the study period, infestations began in July, peaked in November–December, and declined to zero by May–June. Infestation rates differed significantly between years ($p < 0.001$), among regions ($p < 0.001$) and localities ($p < 0.02$), and were influenced by cashew tree phenology ($p < 0.01$), suggesting that *A. terebrans* preferentially infests uncleaned orchards and trees at more vulnerable phenological stages. These findings underscore the need for targeted orchard sanitation practices to reduce infestations, as well as the importance of sampling plans and population monitoring to support higher cashew yields and economic returns.

Keywords: Cashew production, tree phenology stage, cashew wood borer, orchards cleanings, damages distribution

INTRODUCTION

Cashew is a valuable crop for human well-being due to its nutritional content, industrial byproducts, and high global market value (Nair, 2021). Beyond its economic significance, cashew provides substantial income for local communities (Belem, 2017) and presents a viable opportunity for rural development and poverty reduction (Dendena & Corsi, 2014; Sali et al., 2020). However, cashew production faces serious challenges from the *A. terebrans* insect, which leads to growth and yield reductions (Azam-Ali & Judge, 2006; Kekele, 2015; Agboton et al., 2017).

A. terebrans is a significant pest in cashew trees, largely due to its lignin-feeding habit, biological development stages, and host preferences (Oyedokun & Adeniyi, 2016). It is especially destructive in countries such as Benin (Agboton et al., 2014), Ghana (Dwomoh et al., 2008), and Burkina Faso (Nébié et al., 2022). The pest population has increased so much that cashew production in Nigeria, Togo, Senegal, and Burkina Faso is projected to decline within the next two years due to rising insect-pest and disease infestations (Kolliesuah et al., 2020).

The impact of *A. terebrans* on cashew trees is evident, as adult beetles bore into stems, branches, and trunks to lay eggs, while larvae develop within dead wood, producing sawdust that accumulates at the tree base, indicating active infestation (Agboton et al., 2017). The beetle's destructive activity is found across Africa, the Arabian Peninsula, and South and Central America. The tunnel-boring weakens cashew trees, often leading to branch snapping during storms and eventual death of younger trees (Guessan et al., 2017; Borowski, 2021).

Current control measures include pruning affected branches, inserting plugs in active holes, and applying insecticides in Burkina Faso (Somda, pers. obs.). However, these methods have limited effectiveness, as infestation rates continue to rise annually (Agboton et al., 2017; Kra et al., 2017; Binyason et al., 2020). The primary limitation of these methods is that they lack a scientific basis grounded in the insect's biology, ecology, and population dynamics, essential elements for effective pest control.

Further research is needed to understand the population dynamics of *A. terebrans*, given its cryptic lifestyle within tree stems. Collecting quantitative data on its temporal and spatial distribution is critical (Taylor, 1984) to develop informed pest management strategies (Juliano, 2007). Such data would enable prediction of infestation in unmonitored areas and support the creation of efficient sampling plans (Madadi et al., 2011). Currently, there is limited data on infestation rates and pest population dynamics for cashew orchards, not only in Burkina Faso but also in other regions where this pest is a concern.

This study aims to determine the infestation rates of *A. terebrans* in Burkina Faso's cashew orchards, considering different orchard management practices. The results will provide baseline data needed for effective cashew production, pest monitoring, and sampling plans, as well as underscore the urgent need for pest control to ensure sustainable cashew production.

METHODS

Field sites selection and description

Systematic sampling using the spatial and sequential abundance pattern of *A. terebrans* were performed in the South and West parts of Burkina Faso with more than 95% of the national cashew raw nuts production (Audouin & Gonin, 2014) in four regions: Cascades, Hauts basin, Sud Ouest in the Soudanian zone and Centre Ouest in the Soudano-sahelian zone (Belem, 2017; Wonni et al., 2017). In the Soudanian zone, orchards were pruned once and cleaned at least two times/year and in the Soudano-sahelian zone there were not pruned but cleaned solely once/year. In each of the agro-ecological zones, four villages (localities) were randomly selected as Banfora, Bobo, Bouroum-Bouroum and Nako included in the Soudanian zone and Kassou, Leo, Sapouy and Yalle included in the Soudano-sahelian zone. Orchards in these localities were distant to each other for at least 20 to 100 km and 2 cashew plantations were selected in each village based on their age (20–25 years), randomly planted with size >1 ha, no fertilizer or chemical insecticides use looking at the plantation age.

Study area

The study was conducted in South-soudanian (Soudanian zone) and North-soudanian (Soudano-sahelian zone) with rainfall ranked to more than 900 mm and between 600-900 mm/year respectively (Ibrahim, 2013). The production of cashew nuts in these two agro-ecological zones represents 95% of the national cashew raw nuts production (Audouin & Gonin, 2014) and within four regions as Cascades, Centre Ouest, Hauts bassin and Sud Ouest (Belem, 2017; Wonni et al., 2017). Climatic zones of Burkina Faso showing cashew production regions (Wonni et al., 2017).

The monitoring of *A. terebrans* population was done through the galleries it dug inside the cashew trees (Agboton et al., 2017; Aliko & N'goran, 2022). Thus, in this study, a fresh gallery was equivalent to one individual of *A.*

terebrans, although sometimes two individuals could be found in it (Aliko & N'goran, 2022). The monitoring was done from July 2021 to June 2022 for year 1 and from July 2022 to June 2023 for year 2 in accessible cashew orchards throughout the two years. The characteristic of the plantation (phenology), the number of cleanings and pruning, the number of broken branches and Oecophylla longinoda nests were recorded. Based on the above criteria, a total of 16 cashew orchards were selected and 960 trees were monthly monitored.

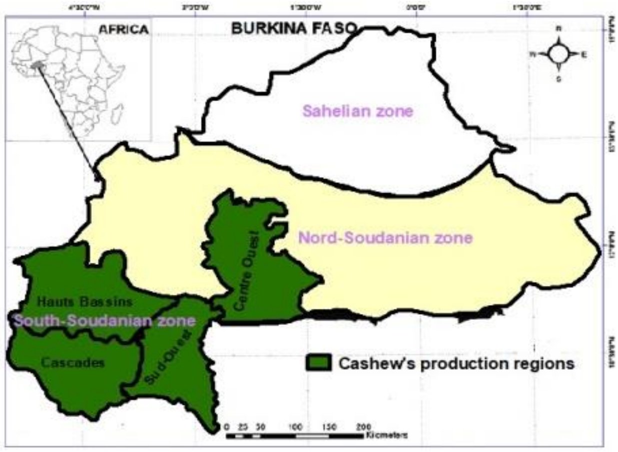

Figure 1. Study area

Data collection and assessment of A. terebrans population

In each cashew orchard, at least 25 trees were randomly selected each year and labelled with a red marking tape. Sampling was carried out on a monthly basis. On each cashew tree, the holes caused by the wood-boring activity of adult *A. terebrans* were classified into three types (Agboton et al., 2017). Lesions caused by *A. terebrans* were monitored on stems, branches and trunk on each tree at East, West, North and South of the tree canopy. On each farm, five non-contiguous blocks (B1, B2, B3, B4 and B5) were delimited (20 m × 20 m), one of each at the four ends and the fifth in the middle. At least five cashew trees labeled were randomly selected in each block and monthly prospected. As a result of the cryptic lifestyle of the cashew wood borer inside the living wood precluding direct observations, the total number of fresh galleries present on the sampled cashew trees represented the population size of *A. terebrans* to determine the infestation rates and the attack's densities of the beetle according to orchards.

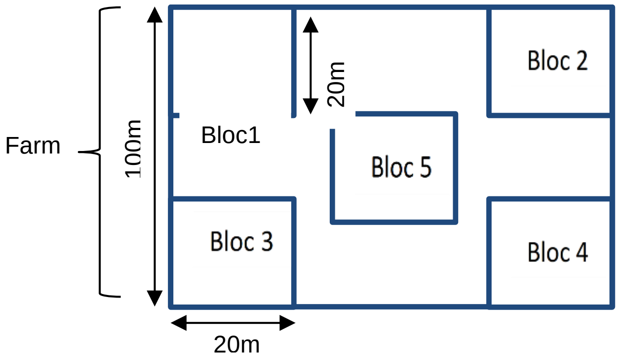

Figure 2. Infestation assessment technique

Statistics analysis

The collected data were processed and analyzed using R software version 4.1.3 (R Team, 2022). As there is violation of parametric assumption of infestation rates following Shapiro-Wilk Normality test we resort to non-parametric tests. We used indeed Paired t-test to compare their medians within the two consecutive years, Kruskal-Wallis Test and Post Hoc test to display influenced factors and finally Spearman's rank correlation for relationship outputs. Graphics were also performed with the same software and statistical differences accepted with 95% as confidence interval.

RESULTS

Incidence of Apate terebrans infestation

Within each orchard, infestation by *A. terebrans* began generally from cashew trees located at the borders and spread to all other areas. Cashew orchards were infested by *A. terebrans* either in Soudanian and Soudano-sahelian zones and infestation increased along the years (Figure 3) and this according to management practices. This infestation rate of the beetle in the Soudanian zone and the Soudano-sahelian zone were significantly different within year 1 and year 2 respectively ($\chi^2 = 83.211$; df = 11; $p < 0.001$; $\chi^2 = 100.31$; df = 11; $p < 0.001$).

In addition, a statistically significant difference was also observed between the two years ($p < 0.001$). In year 1, there were statistically significant differences between infestation rates in all the four regions ($p <0.04$). Throughout localities in year 1, statistical differences were also observed between infestation rates in (Leo, Nako) vs (Banfora; Bobo, Bouroum-Bouroum and Kassou), p <0.01; (Sapouy, Yalle) vs (Banfora, Bobo, Bouroum-Bouroum and Kassou), p <0.001. In year 2, there were significant differences in the infestation rates between regions as Centre Ouest vs Cascades, p = 0.002; Hauts basin vs (Cascades and Centre Ouest), p <0.04 and Sud-Ouest vs (Centre Ouest and Haut basin), p <0.002.

Therefore, there was no significant difference between Sud-Ouest vs Cascades infestation rates, p >0.05. According to localities in year 2, there were statistical differences in the infestation rates between (Leo, Nako) vs Bobo, p <0.001; Sapouy vs (Banfora, Bobo, Bouroum-Bouroum and Kassou), p <0.002; Yalle vs (Banfora, Bobo, Bouroum-Bouroum, Kassou, Leo and Nako), p <0.001. Infestation rates of *A. terebrans* was also statistically different according to the phenology stage of cashew trees in the consecutive years respectively (χ^2 = 158.54; df = 3; p <0.001; χ^2 = 192.54; df = 3; p <0.001). Within phenology stages in year 1, statistical differences of infestation rates were observed between flowering vs fruiting stages, p =0.01 and between vegetative stage vs (flowering stage and fruiting stage), p <0.001. In year 2, the infestation rates were not significantly different between flowering and fruiting stages (p =0.13) but differ significantly between vegetative vs (flowering and fruiting stage), p <0.001.

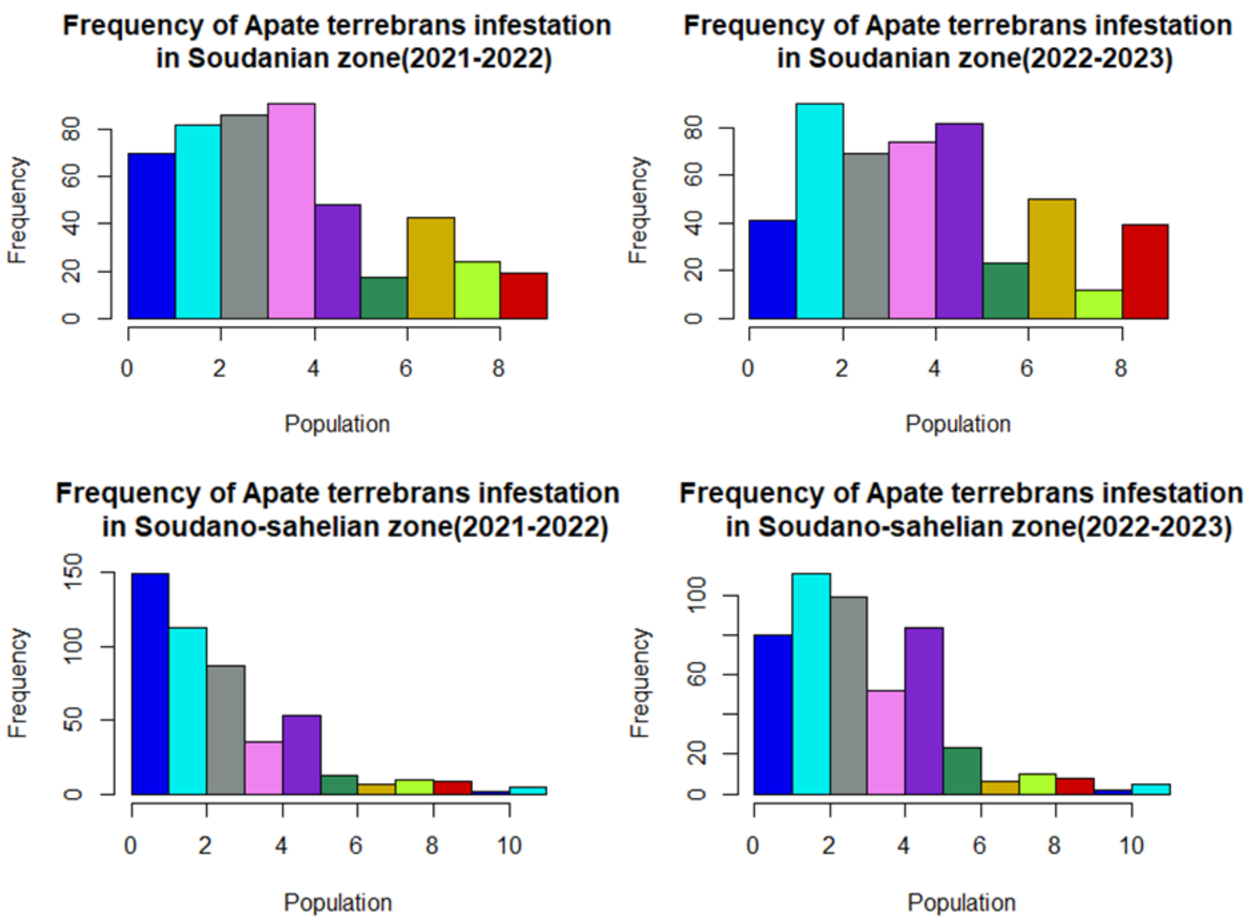

Figure 3. *A. terebrans* infestations rates according to agro-ecological zones.

Variation of A. terebrans population tranches within agro-ecological zones

The population of the *A. terebrans* was smoothly increasing according to years and agro-ecological zones.

Table 1. Relative tranches frequency of *A. terebrans* population within agro-ecological zones

A.terebrans population	**Soundanian year1**	**Soundanian year2**	**Soudano-sahelian year1**	**Soudano-sahelian year1**
[0,3[	0.50	0.42	0.73	0.60
[3,6[	0.32	0.37	0.21	0.33
[6,9[	0.17	0.17	0.05	0.04
[9,12[	0	0.04	0.01	0.02

Notes: Year 1= 2021-2022; Year 2= 2022-2023

Correlation of A. terebrans population and branches broken across some continuous variables

A. terebrans population was positively correlated to *O. longinoda* nests in the Soudanian zones of the two consecutive years respectively (p <0.001, Rho= 0.41, p <0.001, Rho =0.37); negatively correlated in the Soudano-sahelian zone (p =0.05, Rho =-0.09) of year 1 but was not significant and negative in year 2 (p =0.23, Rho =-0.05). Regarding plantation age, *A. terebrans* population was positively correlated in the Soudanian zones but negatively correlated in Soudano-sahelian zones of the consecutive years respectively (p <0.001, Rho =0.26; p <0.001, Rho =0.22; p =0.08, Rho =-0.08; p =0.001, Rho =-0.14). The population was positively correlated with broken branches in the Soudanian zones and Soudano-sahelian zones of the two years respectively (p =0.001, Rho =0.70; p <0.001, Rho =0.30; p <0.001, Rho =0.46; p <0.001, Rho =0.21). There was not relationship between *A. terebrans* population and number of orchards cleaning (p >0.05). The relationship patterns of broken branches and cashew plantation age were during the years dissimilar for the two agro-ecological zones. It was positively correlated in the two consecutive Soudanian zones respectively (p <0.001, Rho =0.24; p =0.0002, Rho =0.17) but was not in the Soudano-sahelian zones (p >0.05). In addition, broken branches were negatively correlated to orchards cleaning number in the Soudano-sahelian zone of year 1 (p =0.02, Rho =-0.11); positively correlated in the Soudanian zone of year 2 (p =0.0005, Rho =0.16); negatively correlated in the Soudano-sahelian zone of year 2 (p <0.001, Rho =-0.19).

Table 2. Correlation of *A. terebrans* population according to agro-ecological zones

Factors	**Variables**	**Soudanian zone**		**Soudano-sahelian zone**		**Soudanian zone**		**Soudano-sahelian zone**	
		Year 1 (2021-2022)				**Year 2 (2022-2023)**			
		P-value	**Rho**	**P-value**	**Rho**	**P-value**	**Rho**	**P-value**	**Rho**
AT pop.	O.l nests	<0.001	0.41	0.05	-0.09	<0.001	0.37	0.23	-0.05
	Plant age	<0.001	0.26	0.08	-0.08	<0.001	0.22	0.001	-0.14
	Branch broken	0.001	0.70	<0.001	0.46	<0.001	0.30	<0.001	0.21
	Cleanings	0.57	0.02	0.93	-0.004	0.53	0.03	0.17	0.06
Branch broken	Plant age	<0.001	0.24	0.77	-0.01	0.0002	0.17	0.46	-0.03
	Cleanings	0.47	0.03	0.02	-0.11	0.0005	0.16	<0.001	-0.19

Note : O. l = *Oecophylla. Longinoda*; A T pop. = *A. terebrans* population

DISCUSSION

This study presents significant insights into the spatial and sequential infestation dynamics of the cashew wood borer, *Apate terebrans*, marking the first research of this kind since the insect was recognized as a substantial threat to cashew production in Burkina Faso (Nébié et al., 2022). The findings highlight how *A. terebrans* infests cashew orchards in both agro-ecological zones where cashews are cultivated, with a preference for older trees (Agboton et al., 2017; Somda et al., 2023). The study also reveals that infestation peaks during the flowering and fruiting flush phases, periods when cashew trees are particularly susceptible and appealing to the beetle (Kra et al., 2017).

The infestation of *A. terebrans* begins simultaneously each year, around July, across both agro-ecological zones. The population dynamics of the beetle closely follow the host's production cycle, a pattern previously observed in Cote d'Ivoire's cashew orchards (Agboton et al., 2017). Similar trends have been reported in studies of other cashew pests, such as *Diastoscera trifasciata*, with infestations rising progressively from July and peaking between November and December as the seasons shift (Aliko & N'goran, 2022; N'Goran et al., 2020). In Burkina Faso, the infestation by *A. terebrans* reaches its peak in January and February, during the flowering stage, and declines as the trees progress to fruiting and vegetative stages, which ultimately impacts cashew tree growth and yields (Agboton et al., 2017). The flowering and post-flowering stages are crucial, as the biochemical composition of the plants is enriched with compounds that can attract a higher diversity of insect pests (Bouyahya et al., 2017), often exploited for bioactive molecules in medical applications (Mounira et al., 2022).

A notable observation during this study was that *A. terebrans* causes substantial damage to the cashew trees, with infested branches often drying up and breaking off, especially under strong winds, or remaining desiccated and clinging to the trees, a phenomenon similarly documented with *D. trifasciata* (Binyason et al., 2020). Importantly, *A. terebrans* was the only wood borer beetle species observed in the cashew orchards across both zones throughout the study. The findings suggest an ongoing and alarming spread of this pest across West Africa, with infestation rates gradually increasing each year (Agboton et al., 2017; Aliko & N'goran, 2022). This trend is indicative of a broader issue, as damage from cashew insect pests has been reported worldwide, with particular concern in African nations, where cashew production is increasingly at risk (Kolliesuah et al., 2020). For instance, infestation rates for *A. terebrans* were reported as high as 54% and 90% in Benin during 2010 and 2011, respectively (Agboton et al., 2017), 17% to 23% in Central Africa (Bosu et al., 2019), and 44% in Burkina Faso (Somda et al., 2023), with a steady increase of 1.8% in Cote d'Ivoire (Aliko & N'goran, 2022).

The damage inflicted by insect pests on cashew trees can be attributed to several factors, including the pests' feeding habits, host preferences, and biological stages, all of which are linked to environmental conditions such as rainfall (Oyedokun & Adeniyi, 2016; Akessé et al., 2018). These factors vary across different years and rainfall patterns (Asogwa et al., 2011; Akessé et al., 2018; Diabate & Tano, 2020). Notably, *A. terebrans* larvae tend to infest dead or decaying wood, aligning with the common behavior of Bostrichidae larvae, which are rarely found on live trees (Waller et al., 2007; Agboton et al., 2017). These larvae depend on wood with a high starch content, commonly found in felled or dying trees, for their development (Waller et al., 2007). Traditional practices such as removing dead or decaying branches and trunks can effectively reduce local infestation sources, as pruning minimizes the habitats available to the wood borer, which aligns with the approach used in controlling *D. trifasciata* larvae (Akessé et al., 2020).

In Burkina Faso's agro-ecological zones, variations in beetle populations were noted, with higher populations recorded in the Soudano-Sahelian zone, though the beetles were more frequently observed in the Sudanian zone. The latter was where cashew trees were initially introduced and where agricultural and forestry services established pilot orchards, which subsequently spread to other regions through neighboring plantations and farmer practices (Ruf, 2016). Differences in infestation levels between regions were attributed to variations in rainfall, orchard management practices, and tree density. These conditions are conducive to pest severity, a concept supported by findings on sunflower plantations where lower plant spacing led to higher pest infestation and subsequent yield loss (Akinkunmi et al., 2012).

The presence of *Oecophylla longinoda* nests was also associated with lower infestation rates by *A. terebrans*, suggesting a potential biological control role for *O. longinoda* in cashew orchards, especially in the Sudanian zone where pruning and the generation of new foliage may support nest establishment. The efficacy of *O. longinoda* in pest control has been demonstrated in studies involving cashew pests like *Helopeltis spp.* and *Pseudotheraptus wayi*, where *O. longinoda* was shown to be as effective, if not more so, than certain insecticides (Olotu et al., 2012; Abdulla et al., 2015; Dwomoh et al., 2009).

CONCLUSIONS

A. terebrans was attacking cashew orchards in both agro-ecological zones, increasing according to years, varying within regions, localities and was impacting its host, the cashew trees. Phenology of cashew trees, pruning and cashew orchards management practices were determinant for this beetle infestation rates density. Unpruned and cleaned solely once cashew orchards were suitable for this insect-pest occurrence. The infestation rates were dependent to *O. longinoda* nests, the number of broken branches and cleanings. The Soudanian zone was the most infested than the Soudano-sahelian although the higher population of the beetle was found in this latest zone. This information on the infestation rates of *A. terebrans* is essential for suitable cashew production, the development of an efficient sampling plans and monitoring of *A. terebrans* population in cashew orchards and to raise an urgent need of *A. terebrans* control for sustainable cashew production.

ACKNOWLEDGMENT

Gratitude to:

1. African Union for awarding me grant for a Ph. D in Environmental Management Programme.
2. Cashew producers for their assistance in field.
3. Local organization leaders for contacts and interactions in all the study sites for the availability of cashew orchards.

REFERENCES

Abdulla, N. R., Rwegasira, G. M., Vagn, K., Mwatawala, M. W., & Offenberg, J. (2015). Effect of supplementary feeding of Oecophylla longinoda on their abundance and predatory activities against cashew insect pests. *Biocontrol Science and Technology*, *15*(11), 1333–1345. https://doi.org/10.1080/09583157.2015.1057476

Agboton, C., Onzo, A., Korie, S., Vidal, M., & Tamo, S. (2017). Spatial and Temporal Infestation Rates of *Apate terebrans* (Coleoptera : Bostrichidae) in Cashew Orchards in Benin, West Africa. *African Entomology*, *25*(1), 24–36. https://doi.org/10.4001/003.025.0024

Agboton, C., Onzo, A., Ouessou, F. I., Goergen, G., Vidal, S., & Tamo, M. (2014). Insect Fauna Associated With Anacardium occidentale (Sapindales : Anacardiaceae) in Benin , West Africa. *Journal of Insect Science*, *14*, 1–12. https://doi.org/10.1093/jisesa/ieu091

Akessé, E. N., Goran, S. M. O.-N., & Dépo, O. R. N. (2018). Population fluctuation of Diastocera trifasciata (Fabricius , 1775) (Coleoptera : Cerambycidae), cashew branches girdler in the Brobo locality (Central Côte d ' Ivoire). *Journal of Entomology and Zoology Studies These*, *6*(5), 1064–1070. http://www.entomoljournal.com

Akessé, E. N., Mauricette, S.-W., Goran, O. N., Minhibo, Y. M., Misler, K., & Koné, D. (2020). Efficacité d ' une lutte mécanique associée au biopesticide Neco 50 EC dans le contrôle des adultes de Diastocera trifasciata (Coleoptera : Cerambycidae), ciseleur des branche s d ' anacardier en Côte d ' Ivoire Efficacy of mechanical control associated. *Int. J. Biol. Chem. Sci.*, *14*(3), 1038–1051. https://doi.org/10.4314/ijbcs.v14i3.3

Akinkunmi, O. ., Akintoye, H. ., Umeh, V. ., & AdeOluwa, O. . (2012). Influence of spacing on the feeding activities of major pests of sunflower and their associated damage Influence of spacing on the feeding activities of major pests of sunflower and their associated damage. *Agriculture and*

Biology Journal of North America, *3*(6), 233–236. https://doi.org/10.5251/abjna.2012.3.6.233.236

Aliko, Y. J., & Mauricette N'goran, O. (2022). Seasonal Fluctuation of The Populations of The Stem Borer, *Apate terebrans* (Coleoptera: Bostrichidae) in Cashew Orchards in North-Eastern Côte d'Ivoire (West Africa) Aliko. *Egyptian Academic Journal of Biological Sciences Entomology*, *15*(4), 1–12. https://doi.org/10.21608/EAJBSA.2022.265487

Asogwa, E. U., T.C.N., N., & A.T., H. (2011). Distribution and damage characteristics of Analeptes trifasciata Fabricius 1775 (Coleoptera : cerambycidae) on cashew (Anacardium occidentale linnaeus 1753) in Nigeria. *Agriculture and Biology Journal of North America*, *2*(3), 421–431. https://doi.org/10.5251/abjna.2011.2.3.421.431

Audouin, S., & Gonin, A. (2014). L'anacarde : produit de la globalisation, moteur de la territorialisation, l'exemple du Sud du Burkina Faso. *Echo Géo*, *29*, 13 p. https://doi.org/10.4000/echogeo.13926

Azam-Ali, S. H., & Judge, E. C. (2006). *Small-scale cashew nut processing*. http://www.fao.org/ag/ags/agsi/Cashew/Cashew.htm

Belem, B. C. D. (2017). *Analyse des déterminants de l'adoption des bonnes pratiques de production de l'anacarde au Burkina Faso*. http://hdl.handle.net/20.500.11794/27700

Binyason, S. A., Baka, S. D., Marchelo, P. W., Duku, J. S., & Ogwaro, A. (2020). The Discovery of a Green Wood Beetle. *Journal of Agricultural Science and Technology*, *10*, 191–199. https://doi.org/10.17265/2161-6256/2020.04.003

Borowski, T. (2021). World Inventory of Beetles of the Family Bostrichidae – Check List – Family Bostrichidae Latreille , 1802. *World News of Natural Sciences*, *36*, 9–41. http://www.worldnewsnaturalsciences.com/

Bosu, P. P., M.M., A., L., A., & D., M. (2019). Status and trends of forests and tree pests and diseases in West and Central Africa. *African Journal of Rural Development*, *4*(1), 93–107. www.afforum.org.

Bouyahya, A., Dakka, N., Talbaoui, A., Et-Touys, A., El-Boury, H., Abrini, J., & Bakri, Y. (2017). Correlation between phenological changes, chemical composition and biological activities of the essential oil from Moroccan endemic Oregano (Origanum compactum Benth). *Industrial Crops and Products*, *108*(May), 729–737. https://doi.org/10.1016/j.indcrop.2017.07.033

Dendena, B., & Corsi, S. (2014). Cashew, from seed to market: A review. *Agronomy for Sustainable Development*, *34*(4), 753–772. https://doi.org/10.1007/s13593-014-0240-7

Diabate, D., & Tano, Y. (2020). Attaque de Analeptes trifasciata Fabricus 1775 (Coleoptera : Cerambycidae) en culture d'anacarde (Anacardium occidentale) .... *Revue Internationale Des Sciences et Technologie*, *36*, 1–10. http://www.revist.ci

Dwomoh, E. A., Ackonor, J. B., & Afun, J. V. K. (2008). Survey of insect species associated with cashew (Anacardium occidentale Linn.) and their distribution in Ghana. In *African Journal of Agricultural Research* (Vol. 3, Issue 3). http://www.academicjournals.org/AJAR

Dwomoh, E. A., Afun, J. V. K., Ackonor, J. B., & Agene, V. N. (2009). Investigations on Oecophylla longinoda (Latreille) (Hymenoptera: Formicidae) as a biocontrol agent in the protection of cashew plantations. *Pest Management Science*, *65*(1), 41–46. https://doi.org/10.1002/ps.1642

Guessan, N. ', Carine, A., Robert, O., Depo, N. ', Robert N'depo, O., Cherif, M., Johnson, F., Fernand, K., Kassi, J.-M., Carina N'guessan, A., Silue, N., Akesse, E. N., Kone, D., & Mauricette N'goran, O. (2017). Inventaire des insectes ravageurs du verger anacardier dans les régions de Bounkani, Gontougo et Indénie-Djablun au Nord-Est en Côte d'Ivoire. *Afrique SCIENCE*, *13*(2), 333–343. http://www.afriquescience.info

Ibrahim, B. (2013). *Caractérisation des saisons de pluies au Burkina Faso dans un contexte de changement climatique et évaluation des impacts hydrologiques sur le bassin du Nakanbé To cite this version : HAL Id : tel-00827764 Docteur ès SCIENCES contexte de changement climat* [Universite Pierre et Marie Curie]. https://tel.archives-ouvertes.fr/tel-00827764

Juliano, S. A. (2007). POPULATION DYNAMICS. *Journal of the American Mosquito Control Association* , 265-275.

Kekele, A. (2015). *Dynamique des paysages ruraux et systeme de production dans la commune de Orodara (Ouest du Burkina Faso)* [Universite Paris I Pantheon-Sorbonne]. https://www.documentation.ird.fr/hor/fdi:010068448

Kolliesuah, N. P., Saysay, J. L., Zinnah, M. M., Freeman, T. A., & Chinenye, D. (2020). Trend analysis of production, comsumption and export of cashew crop in West Africa. *African Crop Science Journal*, *28*(1), 187–202. https://doi.org/10.4314/acsj.v28i1.14S

Kra, K. D., Kwadjo, K. E., Douan, B. G., Kouame, K. L., Ouattara, K. V., & Doumbia, M. (2017). Évaluation des dégâts de Analeptes trifasciata (Coleoptera : Cerambycidae) sur les anacardiers dans les régions du Béré et de l ' Iffou (Côte d ' Ivoire). *Journal of Applied Biosciences*, *112*, 10969–10977. https://doi.org/10.4314/jab.v112i1.1

Madadi H., Dashti F., & Enkegaard A. (2011). Spatial distribution of Thrips tabaci and development of a fixed-precision sampling plan for greenhouse cucumber. *Journal of Entomology* , *8*(3), 280–287.

Mounira, G. M., Ahlem, Z., Mariem, B. A., Romdhane, M., Okla, M. K., Al-Hashimi, A., Alwase, Y. A., Madnay, M. M., Abdelgayed, G., Asard, H., Beemste, G. T. S., & Abdelgawad, H. (2022). Essential Oil Composition and Antioxidant and Antifungal Activities of Two Varieties of Ocimum basilicum L. (Lamiaceae) at Two Phenological Stages. *Agronomy*, *12*(4), 1–17. https://doi.org/10.3390/agronomy12040825

Nair. (2021). *Tree Crops* (K. P. Nair, V. G3, & M. Pankajakshy (eds.); Springer N). https://doi.org/10.1007/978-3-030-62140-7

Nébié, K., Coulibaly, S. L. C. S., Dabiré, R. A., Sankara, F., & Zida, I. (2022). Insect fauna associated with Anacardium occidentale (Sapindales : Anacardiaceae) in the South Sudanese area of Burkina Faso , West Africa. *Entomological Research*, *45*(February), 839–850. https://doi.org/10.5958/0974-4576.2021.00131.6

Olotu, M. I., Plessis, H., Segunic, Z. S., & Maniania, N. K. (2012). Efficacy of the African weaver ant Oecophylla longinoda (Hymenoptera : Formicidae) in the control of Helopeltis spp . (Hemiptera : Miridae) and Pseudotheraptus wayi (Hemiptera : Coreidae) in cashew crop in Tanzania. *Pest Management Sciences*, *69*, 911–918. https://doi.org/10.1002/ps.3451

Ouali N'Goran San-Whouly Mauricette, Koffi Kouassi Misler, A. E. N., & Prisca, G. E. (2020). Morphométrie des adultes de Diastocera trifasciata (Fabricius , 1775) (Coleoptera : Cerambycidae), ciseleur des branches d ' anacardiers dans la région du Gbêkê (Centre de la Côte d ' Ivoire). *Journal of Applied Biosciences*, *148*, 15230–15238. https://doi.org/10.35759/JABs.148.7

Oyedokun, A. V, & Adeniyi, D. O. (2016). Microbial Diversity in the Gut of Cashew Stem Girdler , Analeptes trifasciata Fabricius (Coleoptera : Cerambycidae), in Ibadan , Nigeria. *International Journal of Insect Science*, *8*, 17–22. https://doi.org/10.4137/IJIS.S31265

Ruf, F. (2016). « Une femme en Côte d ' Ivoire , une femme au Burkina Faso »Changement écologique et social autour du cacao... et de l'anacarde. *Echo Géo*, *37*(11 October 2016), 25 p. https://doi.org/10.4000/echogeo.14696

Sali, B., Madou, C., & Nome, A. (2020). Caractérisation socio-économique des grands bassins de productions d ' anacardier s (Anacardium occidentale) et étude comportementale de leur peuplement dans le Cameroun septentrional Socio-economic characterization of the large cashew production basins. *International Journal of Biological and Chemical Sciences*, *14*(6), 2094–2111. https://doi.org/10.4314/ijbcs.v14i6.2

Somda, Z. N. I., Ugwu, J. A., & Dao, M. C. E. (2023). Comparison of some characteristics of cashew nut production in two agroecological zones of Burkina Faso. *Cogent Food & Agriculture*, *9*(2). https://doi.org/10.1080/23311932.2023.2272489

Taylor, L. R. (1984). Assessing And Interpreting The Spatial Distributions Of Insect Populations. *Annual Review of Entomology*, *29*, 321. – 357. www.annualreviews.org

Team, R. C. (2022). *A language and environment for statistical computing. R Foundation for Statistical Computing*. R Foundation for Statistical Computing. https://www.r-project.org/.

Waller J.M., Bigger M., & Hillock R.J. (2007). *Coffee Pests, Diseases and their Management.* http://sherekashmir.informaticspublishing.com/654/1/9781845931292.pdf

Wonni, I., Sereme, D., Kassankagno, A. I., Dao, I., Ouedraogo, L., & Nacro, S. (2017). Diseases of cashew nut plants (Anacardium occidentale L .) in Burkina Faso. *Advances in Plants & Agriculture Research*, *6*(3), 78–83. https://doi.org/10.15406/apar.2017.06.00216