International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 01-02-2025, Accepted: 03-03-2025, Published: 19-03-2025
Volume 10, Issue 1, 2025, Page No. 38-44

Agroecological factors influencing the population dynamics of *Toxoptera Aurantii* Boyer (Hemiptera: Aphididae) on cocoa trees in the Centre Region of Cameroon

Mballa Ndzié Paul Arnaud, Yede, Mariam Messie Djegome, Pierre Dimi Mvele, Paul Serge Mbenoun Masse
Laboratory of Zoology, Department of Biology and Animal Physiology, University of Yaoundé I, Cameroon

Abstract

The determination of agroecological factors influencing crop pest populations is essential for the development of integrated pest management programs, due to the variability in pest population dynamics. *Toxoptera aurantii* is one of the key Hemipteran pests affecting cocoa crops in Cameroon. Like other aphid species, its population can reach thousands on cocoa farms; however, the impact of agroecological factors on its population dynamics remains insufficiently explored. This study aimed to assess the population dynamics of *T. aurantii* and examine the effects of agronomic and environmental factors on two cocoa varieties, Forastero and Trinitario, at the Libelligoi cocoa farm from January 2019 to December 2020. To carry out this investigation, monthly observations were conducted, wherein the number of aphids on chupons and flushes was counted. Our results indicate that the population dynamics of *T. aurantii* varied over time, with higher populations observed on chupons compared to flushes. This variation was closely linked to the vegetative activity of the cocoa trees, particularly the rate of appearance of flushes and chupons. However, there was no clear correlation between aphid population numbers and the number of chupons or flushes, suggesting that other factors, aside from the presence of these vegetative structures, influence aphid populations. Additionally, environmental factors such as humidity may play a role in aphid emergence. When considering the effect of cocoa variety and the nature of the host plant, we observed a tendency for aphid populations to be more closely correlated with the rate of appearance of chupons and flushes in single-variety cultivations. This dependency was more pronounced in the Trinitario variety, while it remained less significant in the Forastero variety. These findings underscore the critical role of agronomic factors and cultural practices in shaping aphid population dynamics. Our study highlights the importance of periodic removal of chupons from cocoa trees as a potential management strategy for controlling aphid populations.

Keywords: *Toxoptera aurantii,* agroecological factors, population dynamics, variety

Introduction

In agroecosystems, a range of environmental and agronomic factors influence the distribution and abundance of pest species (Pedigo & Rice, 2008; Ehrlén & Morris, 2015) [10, 21]. Sustainable pest management necessitates a comprehensive understanding of the factors that mediate the persistence of pest species and their population dynamics (Pedigo & Rice, 2008; Price *et al*., 2012) [21, 23]. Agricultural landscapes often exhibit significant variability in habitat composition and other environmental conditions. Therefore, identifying the environmental factors and management practices that foster abundant and diverse pest communities is essential for the development of effective pest control strategies (Pedigo & Rice, 2008; Price *et al*., 2012) [21, 23].

The cocoa aphid, *Toxoptera aurantii* Boyer, 1941, causes direct damage by feeding on significant quantities of phloem sap from its host plants and is the most abundant aphid species found in cocoa farms of the Centre Region in Cameroon (Yede, 2016) [33]. The direct damages caused by *T. aurantii* include leaf curling, premature leaf drop, and the wilting of leaves, as well as young shoots or stems (Fournier, 2010) [11]. In addition to these direct damages, aphids also cause indirect harm, which can be categorized into two main effects : (a) the production of honeydew, which, in the absence of mutualistic ants, fosters the development of sooty mold, and (b) the transmission of plant viruses, such as the tristeza virus in *Citrus* spp. (Brault *et al*., 2010) [7]. The severity of the damage is often directly correlated with aphid population size. *T. aurantii* individuals form dense colonies, and their population density may influence the extent of the damage caused. Therefore, pest management strategies should consider these various types of damage when formulating control measures (Turpeau *et al*., 2011) [28].

The management of cocoa plantations, along with climatic and edaphic factors, significantly influences aphid population dynamics (Tamesse & Messi, 2004; Yede *et al*., 2023) [26, 34]. In Cameroon, as in other countries, cocoa is traditionally cultivated within dense and highly diversified multi-strata vegetation systems (Sonwa *et al*., 2007; Bisseleua & Vidal, 2008; Babin *et al*., 2010) [4, 5, 25]. The impact of these agro-ecological factors is inherently linked to the specific characteristics of the cultivation land. In other words, the extent and intensity of these factors are determined by the type of cultivation system employed.

Agricultural factors such as altitude, irrigation, fertilization, variety selection, climatic conditions, environmental factors, sanitary practices, insect and pest management, and harvesting strategies all play crucial roles. These agro-ecological elements significantly affect vegetative and reproductive growth, flowering, fruit maturation, ripening, fruit and bean size, and ultimately the composition of cocoa beans, which in turn influences the quality of cocoa beverages (Bosselmann *et al*., 2007; Yede *et al*. 2012) [6, 32].

Recent studies have underscored the critical role of sustainable agricultural practices in mitigating pest infestations. For example, maintaining a dense canopy of shade trees in African cocoa farms has been associated with reduced pest burdens and increased populations of potential pollinators and natural predators, thereby enhancing ecosystem services (Bisseleua *et al*., 2008) [5]. Additionally, research indicates that climate change affects the geographical distribution of pests and diseases in cocoa-growing areas, underscoring the need for adaptive management strategies (Cilas & Bastide, 2020)

Understanding the interplay between agro-ecological factors is essential for developing integrated pest management strategies that promote sustainable cocoa production. Seasonal variation in the abundance of tropical insects is a common phenomenon, influenced by factors such as macroclimatic and microclimatic changes, as well as fluctuations in the availability of food resources. Climate change contributes to extreme weather events, including variations in rainfall, increased proliferation of pests, crop diseases, and elevated temperatures, all of which can impact insect populations

Insects often exhibit increased activity and efficiency at higher temperatures, enabling them to feed, develop, reproduce, and disperse more rapidly, albeit with potentially shorter lifespans. Currently, species such as *Myrmicaria opaciventris* Emery, 1893, and *Pheidole megacephala* Fabricius, 1793, are among the most frequent ant species associated with *Toxoptera aurantii*; they appear to positively and significantly impact aphid populations on cocoa farms (Yede *et al*. 2023) [34]. Determining the agro-ecological factors influencing crop pests is crucial for developing effective integrated pest management (IPM) strategies in cocoa-based agroecosystems across Africa. Such approaches can help reduce or eliminate the use of synthetic pesticides, thereby preventing the accumulation of pesticide residues in the environment and food. In this context, the present study aims to monitor the population dynamics of *T. aurantii* by examining the factors that directly or indirectly influence its abundance. Specifically, we investigate whether the abundance of *T. aurantii* varies according to cocoa variety and assess how environmental and agronomic factors affect its population dynamics. Our objective is to identify the primary factors mediating *T. aurantii* abundance.

Materials and methods

Study locality and experimental plots description

A field experiment was conducted on farmer holdings in Libelligoi (3°54.210'N; 10°55.610'E; 400 m a.s.l) over a two-year period, from January 2019 to December 2020. Libelligoi is located in the Ngog-Mapubi subdivision, Nyong et Kéllé Division, Centre Region of Cameroon (Figure 1). The region is characterized by an equatorial climate with four seasons : two rainy and two dry seasons, which alternate irregularly in terms of intensity and duration (Anonymous, 2020) [3]. The average annual temperature is 25.1°C, and the annual rainfall exceeds 2,100 mm (Kanmegne *et al*., 2006) [13]. Detailed data on agricultural practices, flora and fauna composition, and pedological characteristics of the study area are documented (Anonymous, 2020; Yede *et al*., 2023, 2024) [3, 34, 35]. In this locality, cocoa is cultivated under the canopy of natural trees, with no adherence to agronomic recommendations regarding tree spacing within and between rows, which should be 2.5 x 2.5 m or 3 x 3 m for approximately 1,200 cocoa trees per hectare (Anonymous, 2002) [2]. The selected cocoa trees were recorded using the Global Positioning System (GPS) and covered approximately à quarter of the cocoa plantation. Each plot contained both cocoa varieties : Trinitario or hybrids from the IRAD Research Station in Yaoundé, and Forastero or Amelonado (German cocoa).

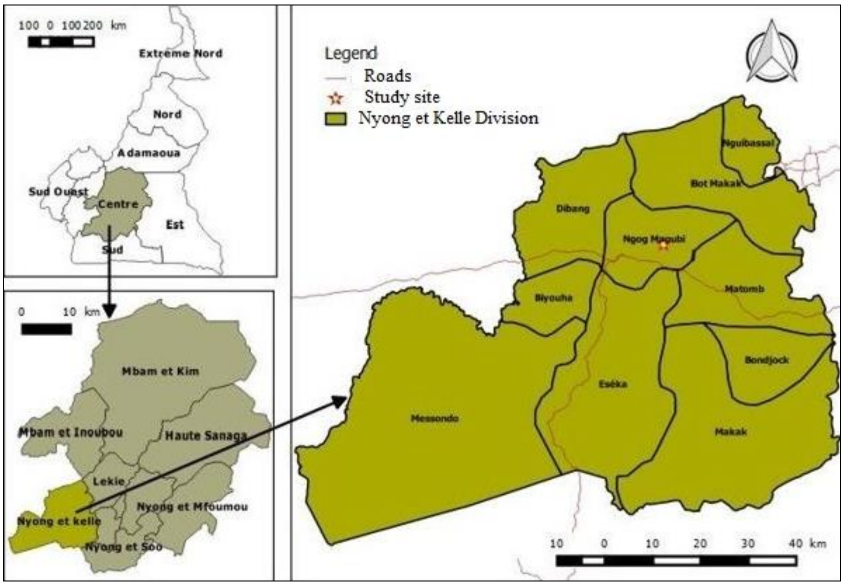

Fig 1 : study site

Choice of experimental plots and cocoa varieties

Four one-hectare plots were selected after surveying a series of plantations in the locality, based on the presence and numerical representativeness of cocoa varieties on the site, in November 2018, when the cocoa trees were still bearing fruit. Initially, 120 cocoa plants (encompassing all varieties) or 30 plants per plot, with all varieties combined, were randomly selected through a random draw and labeled for the study of aphid population dynamics, without considering the varieties. Additionally, 60 plants of two specific cocoa varieties Forastero and Trinitario were chosen and labeled, with 30 plants per variety, based on their botanical characteristics (Mossu, 1990) [19], such as the color and shape of their fruits.

Monitoring of aphid populations

Aphids were sampled on chupons and flushes of cocoa trees, which were labeled once a month. The procedure involved counting and labeling all chupons and infested flushes present on the labeled cocoa trees. Subsequently, the first three leaves of each chupon/flush, located around the crown, were numbered, and one leaf was randomly selected for aphid counting through a random draw. Aphids were counted on each chupon/flush, and the data were recorded on a dedicated collection sheet. Finally, the average number of aphids per chupon/flush was calculated monthly in the plots using the following formular :

$$\mathrm{Nma} = \frac{\sum(\mathrm{ag}/\mathrm{af})}{(\mathrm{ng}/\mathrm{nf})}$$

Nma : average number of aphids counted for the month per chupon or flush leaf; ag : number of aphids from each leaf of chupon taken; af : number of aphids from each flush leaf taken; ng : number of chupons; nf : number of flushes.

Collection of environmental and management data

We recorded data on environmental and agronomic factors to determine their effects on aphid’s population. Using ArcGIS 10.3 software, monthly climate data (temperature, precipitation and humidity) were recorded by entering geographical coordinates of the explored plots (spatial interpolation).

Data analysis

The average number of aphids was calculated for each plot. To analyze whether the abundance of *T. aurantii* was influenced by environmental (temperature, hygrometry and rainfall) and agronomic factors (varieties, chupons and flushes), Spearman rank correlations were performed between agroecological factors (temperature, humidity, and rainfall). Additionally, the variables precipitation, humidity, temperature, chupon, and variety were incorporated into a series of Generalized Linear Models (GLM) to evaluate their individual or combined effects on the abundance of skink species with more than five records. The best-performing model was selected based on the smallest Akaike's Information Criterion (AIC; Mazerolle, 2004) [16]. All analyses were conducted using the statistical software R v. 4.0.3 (R Core Team, 2020) [24].

Results

Influence of agronomic parameters on population dynamics of *Toxoptera aurantii*

General (All variety of cocoa)

Over the two-year survey period (2019 and 2020), aphid abundance exhibited temporal variations from January to December (Figure 2). Among the 120 cocoa trees monitored across all varieties, the average number of aphids per chupon leaf, per month, was 206 in 2019 and 172 in 2020. This temporal dynamics revealed four peaks in 2019 compared to three in 2020. In 2019, the most significant peak occurred in February, with 635 individuals per leaf, while in 2020, the peak was observed in June, with 713 individuals per chupon leaf. Following each major annual peak, a decline was noted, reaching the lowest values in April (20 and 0 individuals per chupon leaf) in 2019 and 2020, respectively. Specifically, in 2019, a subsequent increase led to a second peak in June (318 individuals per chupon leaf). From May onwards, slight fluctuations were observed until a third peak of similar magnitude to the second occurred in October (322 individuals per chupon leaf). Conversely, observations in 2020 revealed fluctuations in aphid numbers primarily between April and August (Figure 2). These apparent fluctuations between aphid numbers during the two years were not significantly different, as the autocorrelation test of aphid population dynamics between 2019 and 2020 revealed a positive but non-significant correlation ($R^2 = 0.31$; $p = 0.060$). In 2019, cocoa variety did not significantly influence aphid population dynamics ($R^2 = 0.20$; $p = 0.141$). However, in 2020, the number of cocoa varieties significantly promoted the development of aphid populations ($R^2 = 0.43$; $p = 0.020$).

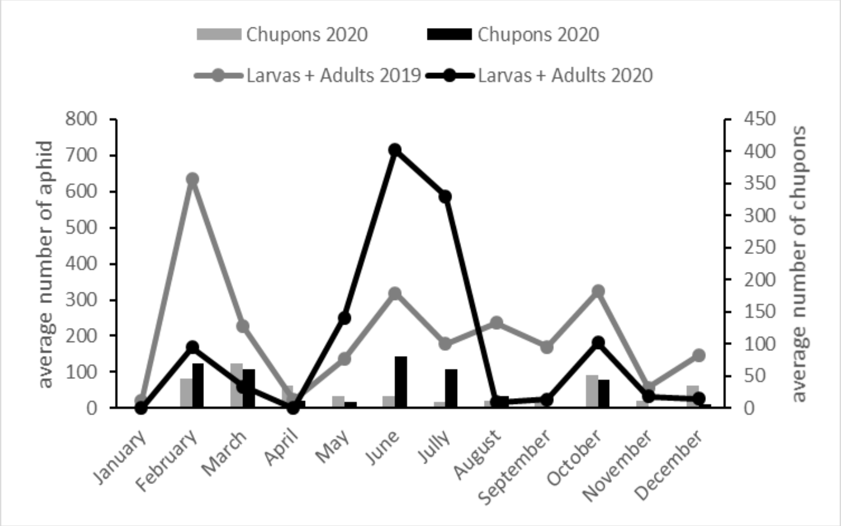

Fig 2: Monthly variations of *Toxoptera aurantii* number on chupon in cocoa farms (2019 and 2020).

Throughout the study period, aphid populations per flush leaf remained consistently low, with counts generally below 100 individuals per leaf (Figure 3). The average number of aphids per flush leaf was 22 across both years. Overall, the population size exhibited a sawtooth pattern, with less pronounced fluctuations throughout the study period, despite the presence of flushes, particularly in 2019. A weak positive but non-significant correlation was observed between aphid population dynamics and flush availability in both 2019 ($R^2 = 0.098$; $p = 0.230$) and 2020 ($R^2 = 0.29$; $p = 0.072$).

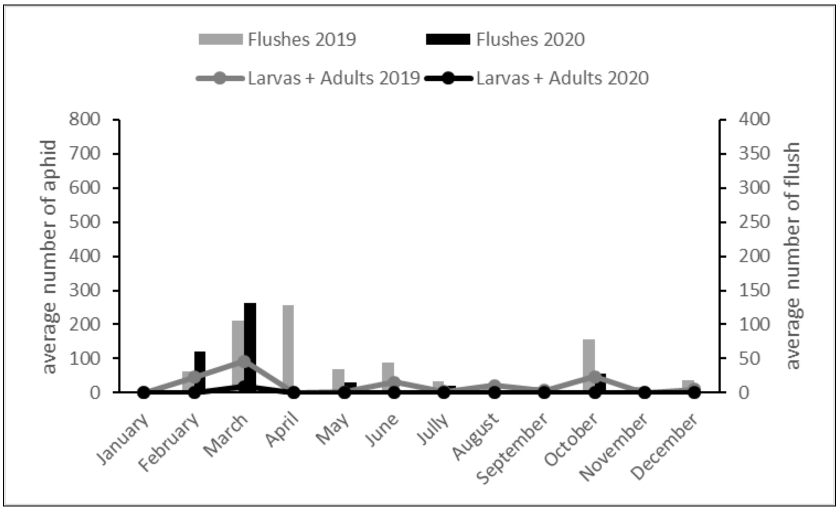

Fig 3: monthly variations of *Toxoptera aurantii* on flushes in cocoa farms (2019 and 2020).

Aphid population dynamics by variety (Trinitario et Forastéro)

The average number of aphids per leaf of the Trinitario variety varied over the two years (Figure 4). In 2019, three peaks of aphid abundance were observed, with the largest occurring in October (380 individuals) and the smallest in February (272 individuals). In 2020, the population dynamics of aphids followed a similar pattern with three peaks, the most significant in June (904 individuals). Between consecutive peaks, the lowest values were recorded in May and August in 2019, and in April and September in 2020. Although the intensity of these peaks varied annually, they occurred during similar periods each year. These fluctuations in aphid numbers over the two years were not significantly different, as the autocorrelation test revealed a positive but non-significant correlation ($R^2 = 0.069$; $p = 0.405$). During the two years of study, a strong positive influence of chupon presence in single-cultured Trinitario on aphid numbers was observed. This influence was reflected each year by a positive correlation ($R^2 = 0.41$; $p = 0.02$ in 2017 and $R^2 = 0.86$; $p < 0.0001$) between the number of chupons and aphid numbers.

Over the two-year study period (2019 and 2020), the average number of aphids per Trinitario cocoa leaf was generally low, with approximately 19 individuals per leaf. Two minor peaks in aphid abundance were observed, corresponding with the dynamics of new leaf growth (flushes). This observation indicates a positive and highly significant correlation between the presence of new leaves and aphid populations in both 2019 ($R^2 = 0.414$; $p = 0.024$) and 2020 ($R^2 = 0.81$; $p < 0.001$).

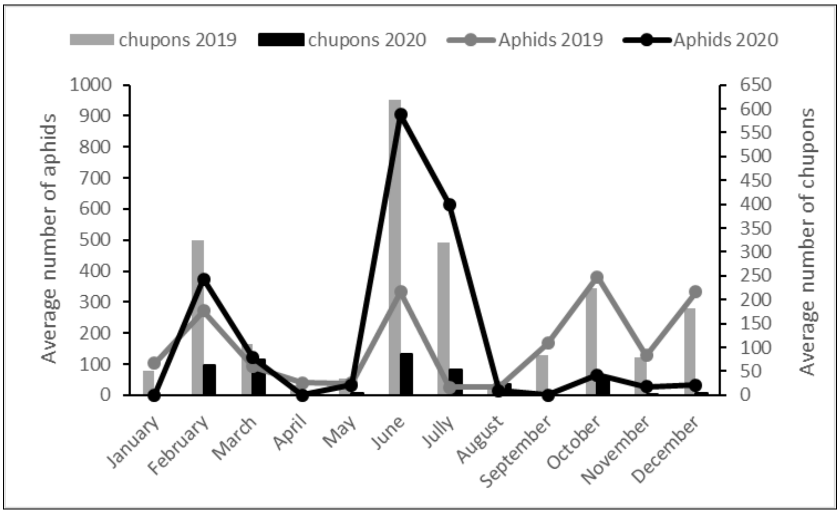

Fig 4: Monthly variation of *Toxoptera aurantii* on chupons of the Trinitario

Over the two-year study period, aphid abundance on Forastero cocoa trees exhibited notable fluctuations (Figure 5). In 2019, aphids were consistently present on chupons, with population dynamics characterized by three peaks, each followed by phases of growth and regression. In contrast, 2020 saw aphid populations absent only in January and April, with numbers exceeding 100 individuals per chupon leaf in all other months. The population peaked in February at 405 individuals per chupon leaf, maintaining fluctuations between 100 and 300 individuals per chupon leaf from May to December. The autocorrelation test revealed a positive, though not statistically significant, correlation between aphid populations in 2019 and 2020 ($R^2 = 0.17$; $p = 0.19$). Throughout both years, aphid dynamics were strongly and significantly correlated with chupon numbers, with R^2 values of 0.739 ($p = 0.033$) in 2019 and 0.87 ($p = 0.002$) in 2020. Despite the continuous presence of flushes throughout the year, aphid numbers and flush dynamics in Forastero cocoa trees did not evolve synchronously. Overall, aphid populations exhibited a sawtooth pattern with two identical peaks in June and August, and a smaller peak in March. The average number of aphids per flush leaf was 23 individuals. Four peaks in abundance were observed, with a weak positive association between flushes and aphid numbers, as indicated by the Spearman correlation test ($R^2 = 0.047$; $p = 0.429$).

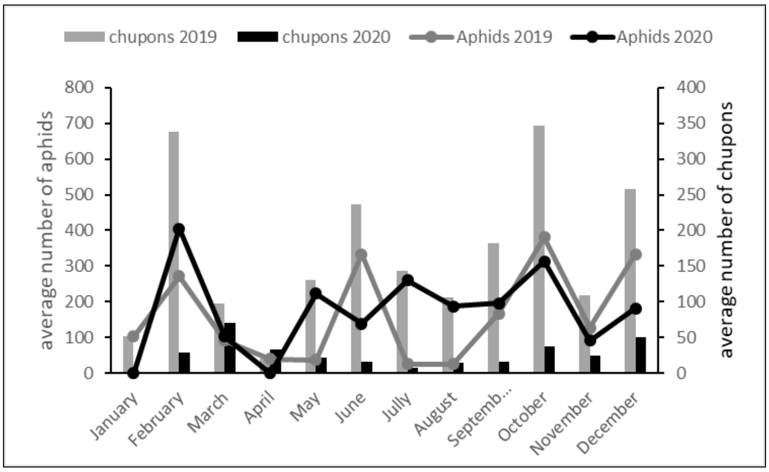

Fig 1: monthly variations of *Toxoptera aurantii* on chupons of forastero.

Influence of climatic parameters on the population dynamics of *Toxoptera auranti*

Despite some weak and insignificant correlations observed between climatic factors and aphid populations in mixed-variety plots (comprising the two varieties), the results indicated that temperature and precipitation did not play a dominant role in the population dynamics of aphids. The influence of these factors was instead dependent on the type of food source (chupon or flush) and the specific year of study. Notably, only humidity significantly and positively impacted aphid population emergence in 2019 ($R^2 = 52\%$, $p = 0.008$) on chupons (Table 1). When examining the different varieties, the findings revealed that, although correlation coefficients between aphid population dynamics and humidity were relatively high and stable across the food sources of the Trinitario variety, no significant effects of climatic factors on aphid population variations were observed (Table 1). In contrast, for the Forestaro variety, humidity was consistently positively correlated with aphid populations. However, this correlation was only statistically significant for aphid populations on chupons in 2019 ($R^2 = 58\%$, $p = 0.004$). Across all observations, irrespective of the variety or year, neither precipitation nor temperature exerted any discernible influence on aphid population dynamics on either chupons or flushes (Table 1).

Table 1: Influence of climatic parameters on population dynamics of *Toxoptera auranti*

Year	**Climatic factors**	**Cocoa variety**					
		All variety of cocoa		**Trinitario**		**Forastero**	
		Aphid on chupons	Aphid on flushes	Aphid onchupons s	Aphid on flushes	Aphid on chupons	Aphid on flushes
2019	Temperature	0.066; p>0.05	0.003; p>0.05	0.118; p>0.05	0.188; p>0.05	0.13; p>0.05	0.139; p>0.05
	Rainfall	-0.0088; p>0.05	0.182; p>0.05	0.239; p>0.05	0.029; p>0.05	0.030; p>0.05	0.029; p>0.05
	Hygrometry	0.718; p< 0.05	0.40; p>0.05	0.271; p>0.05	0.077; p>0.05	0.271; p>0.05	0.271; p>0.05
2020	Temperature	-0.145; p>0.05	0.399 : p>0.05	-0.034; p>0.05	-0.093. p>0.05	-0.062; p>0.05	-0.464; p>0.05
	Rainfall	0.192; p>0.05	-0.043; p>0.05	-0.034; p>0.05	-0.084; p>0.05	0.162; p>0.05	0.162. p>0.05
	Hygrometry	0.371; p>0.05	0.393; p>0.05	0.356; p>0.05	0.369. p>0.05	0.758; p<0.05	0.315; p>0.05

The results of the Generalized Linear Model (GLM) indicate that temperature, precipitation, humidity, and agronomic factors do not operate in isolation, but rather interact concurrently to influence aphid population dynamics in the field. In nature, these factors act simultaneously, rather than independently, on aphid populations. Specifically, the GLM results highlight that the Population dynamics of *T. aurantii* are most strongly influenced by the combined effects of chupon and variety factors, followed by precipitation and temperature. The combined influence of all factors precipitation, humidity, temperature, chupon, and variety also plays a role, but to a lesser extent (Table 2).

Table 2: Generalized linear model (GLM) showing the effect of temperature, humidity, precipitation, chupons and variety on aphid abundance in cocoa farms

Model parameters	**Df**	**Residuals**	**P**	**AIC**	**ΔAIC**
Rainfall*Hygrometry	69	88.33	0.37	864.42	8939.8
Rainfall*Temperature	69	88.53	0.00143 **	869.9	8934.3
Hygrometry*Temperature	69	88.25	0.11	861.55	8942.7
Rainfall*Hygrometry*Temperature	68	88.25	0.13	863.54	8940.7
Chupons *variety	68	88.13	< 2e-16 ***	858.17	8946
Rainfall*Hygrometry*Temperature* Chupons*Variety	65	9377.5	< 2e-16 ***	9804.2	0

Significant Codes : 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Discussion

The interactions between insects, plants, and the ecosystems in which they reside are shaped by environmental variability (Price *et al*., 2012) [23]. Understanding how pests respond to environmental and agronomic factors is crucial for the development of sustainable Integrated Pest Management (IPM) programs (Milosavljevic *et al*., 2016). In plots containing all cocoa varieties, the population dynamics of *T. aurantii* varied over time, being higher on chupons than on flushes. This dynamic appeared to be influenced by the vegetative activity of the cocoa trees, particularly the rate at which flushes and chupons emerged.

However, statistical analyses revealed no significant relationship between the variation in aphid population size and the appearance of chupons and flushes. These results suggest that, when cocoa varieties are mixed, other factors may account for the observed variations. Furthermore, environmental humidity appeared to play a key role in the emergence of aphids during certain periods of the year. Yede *et al*. (2023) [34] showed in their study that the main ant species such as *Myrmicaria opaciventris* and *Pheidole megacephala* associated to *Toxoptera aurantii* individuals on cocoa trees are positively and significantly correlated.

With regard to cocoa varieties and the nature of the food source, the findings of this study indicated a tendency for aphid population dynamics to correlate with the rate of appearance of chupons and flushes. This relationship was particularly evident in single-variety plots, notably in cocoa trees of the *Trinitario* variety, but less pronounced in *Forastero* variety trees. These results underscore the importance of agronomic factors and cultural practices in influencing aphid population variation. In mixed-variety plots, the population dynamics of aphids were not consistently governed by chupons and flushes, as their correlation with aphid populations was either weak or non-significant. In contrast, a significant positive correlation was observed between aphids and these food sources in single-variety plots. Based on these findings, mixing cocoa varieties may serve as à practice to mitigate aphid population emergence.

In cocoa trees, phenolic compounds such as flavonoids play an important role in influencing insect pest attraction, resistance, and tolerance (Van Emden, 1978) [30], and their concentration varies by variety. This compositional difference may make some varieties more palatable, thereby stimulating aphid reproduction. For instance, Abang *et al*. (2014) [1] observed that *Aphis gossypii* was more abundant on the *okra kirikou* variety than on the coffee *okra* variety, despite both varieties showing no significant differences in sugar, tannins, or phenols, but instead differing in nitrogen content, with the kirikou variety containing more nitrogen. Additionally, trichome density was higher on the coffee okra than on the okra kirikou variety. Hadji (2010) [12] reported that *A. gossypii* had greater fertility on cucumber than on cotton, with plant temperature and nutritional value strongly influencing the development, survival, and reproduction of the aphid. The higher aphid abundance on chupons compared to flushes could be attributed to the exposure of aphids to fluctuating ambient temperatures, which may exceed tolerance thresholds and accelerate the transformation of young, soft leaves favored by aphids as a food source. Van Emden and Bashford (1971) [29] noted that young leaves are particularly conducive to aphid development due to their nutrient richness, especially nitrogen. Thus, the intrinsic metabolic properties of each cocoa variety may predispose it to either favor or deter aphid population emergence.

In terms of climatic factors, several studies (Logan *et al*., 2003; Menendez, 2007; Deutsch *et al*., 2008) [8, 15, 17] have highlighted the pivotal role of climate, particularly temperature, in the growth and geographical distribution of insect populations, including aphids. In the specific case of aphids, Tofangsazi *et al*. (2010) [27] demonstrated that mortality rates in aphid immature stages increase rapidly under both low and high temperatures, whereas intermediate temperatures facilitate survival. The temperatures observed during this study fell within the range of intermediate temperatures identified by Tofangsazi *et al*. (2010) [27]. Despite the negative correlation between aphid population emergence and rising temperatures, none of these correlations were significant, nor was there a significant effect of precipitation. In contrast, humidity consistently favored aphid development, particularly in mixed-variety plots and single-variety plots, especially for the *Forastero* variety. This study, similar to the work of Tamesse and Messi (2004) [26] on climatic factors influencing the population dynamics of the African citrus psyllid *Trioza erytreae*, concludes that small variations in climatic factors alone cannot fully account for fluctuations in *T. aurantii* populations in cocoa orchards. Rather, the findings suggest that aphid population dynamics are the result of multiple synergistic interactions that involve both agronomic and ecological factors.

Conclusion

The population dynamics of *T. aurantii* are observable in cocoa-based agroecosystems, particularly on chupons, where significant outbreaks are frequently observed. Cultural practices appear to be a crucial factor whose manipulation could lead to a reduction in *T. aurantii* populations in cocoa farms, particularly in cropping systems involving mixed varieties. In the context of establishing cocoa plots, no single agronomic or ecological factor can be solely credited with governing the population dynamics of cocoa aphids. Rather, these dynamics are shaped by a complex interplay of multiple synergistic factors, integrating both agronomic and ecological elements

Acknowledgement

The authors are grateful to Ntjam Paul and Ngo Ntjam Julienne the cocoa farmers of Libellingoi for providing cocoa plantations to the first author for carrying out the research.

Declaration of Competing Interest

The authors declare no conflict of interest.

References

1. Abang AF, Srinivasan R, Kekeunou S, Hanna R, Chagomoka T, Chang JC, Bilong Bilong CF. Identification of okra (Abelmoschus spp.) accessions resistant to aphid (Aphis gossypii Glover) in Cameroon. Afr Entomol,2014:22(2):273-284.
2. Anonymous. Mémento de l'Agronome. CIRAD, GRET, Ministère français des affaires étrangères, Paris, 2002, 8.
3. Anonymous. Municipal Development Plan of Ngog-Mapubi Sub-Division, including Libelligoivillage. IOP Publishing PhysicsWeb. Retrieved July 2, 2023, 2020. Available from:

https://www.google.com/search?q=Municipal+Development+Plan+of+NgogMapubi+SubDivision%2C+including+Libelligoi+village
4. Babin R, ten Hoopen GM, Cilas C, Enjalric F, Yede Gendre P, Lumaret JP. Impact of shade on the spatial distribution of Sahlbergella singularis in traditional cocoa agroforests. Agric For Entomol,2010:12(1):69-79.
5. Bisseleua BD, Vidal S. Plant biodiversity and vegetation structure in traditional cocoa forest gardens in southern Cameroon under different management. Biodivers Conserv,2008:17:1821-1835.
6. Bosselmann AS, Dons K, Oberthür T, Smith C, Raebild A, Usma H. The influence of shade trees on coffee quality in smallholder coffee agroforestry systems in Southern Colombia. Agric Ecosyst Environ,2007:129(13):253-260.
7. Brault V, Uzest M, Monsion B, Jacquot E, Blanc S. Aphids as transport devices for plant viruses. Comptes Rendus Biol,2010:333(6-7):524-538.
8. Deutsch CA, Tewksbury JJ, Huey RB, Sheldon KS, Ghalambor CK, Haak. The impact of land conversion on plant biodiversity in the forest zone of Cameroon. Biodivers Conserv,2008:11:2047-2061.
9. Drake VA. The influence of weather and climate on agriculturally important insects: An Australian perspective. Aust J Agric Res,1994:45(3):487-509.
10. Ehrlén J, Morris WF. Predicting changes in the distribution and abundance of species under environmental change. Ecology Lett,2015:18(3):303-314.
11. Fournier A. Assessing winter survival of the aphid pathogenic fungus Pandora neoaphidis and implications for conservation biological control. Thèse de Doctorat, Université de Zurich, 2010, 220.
12. Hadji M Takalloozadeh. Effects of host plants and various temperatures on population growth parameters of Aphis gossypii Glover (Homoptera-Aphididae). Middle East J Sci Res,2010:6(1):25-30.
13. Kanmegne J, Smaling EMA, Brussaard L, Gansop-Kouomegne A, Boukong A. Nutrient flows in smallholder production systems in the humid forest zone of southern Cameroon. Nutr Cycling Agroecosyst,2006:76:233-248.
14. Leelananda S, Ranamukhaarachchi, Wickramarachchi KS. Colour preference and sticky traps for field management of thrips, Ceratothripoides claratris (Shumsher) (Thysanoptera: Thripidae) in tomato in Central Thailand. Int J Agric Biol,2007:9(3):406-397.
15. Logan JA, Regniere J, Powell JA. Assessing the impacts of global warming on forest pest dynamics. Front Ecol Environ,2003:1(3):130-137.
16. Mazerolle MJ. Drainage ditches facilitate frog movements in a hostile landscape. Landsc Ecol,2004:20:579-590.
17. Menendez R. How are insects responding to global warming? Tijdschr Entomol,2007:150:355-365.
18. Milosavljevica I, Esserb AD, Crowdera DW. Effects of environmental and agronomic factors on soil-dwelling pest communities in cereal crops. Agric Ecosyst Environ,2016:225:192-198.
19. Mossu G. Le cacaoyer. Maisonneuve et Larose, 1990, 159.
20. NEST (Nigerian Environmental Study/Action Team). Executive summary of five sector surveys on Nigeria's vulnerability and adaptation to climate change. Nigeria, 2004.
21. Pedigo LP, Rice M. Research on Chrysomelidae. Validation and application of predictive models on bean leaf beetle, Cerotoma trifurcata, population dynamics in Central Iowa, 2008, 334.
22. Pinheiro MHO, Monteiro R, Cesar O. Levantamento fitossociológico da floresta estacional semidecidual do Jardim Botânico Municipal de Bauru, São Paulo. Naturalia,2002:27:145-164.
23. Price PW, Denno RF, Eubanks MD, Finke DL, Kaplan I. Insect Ecology: Behavior, Populations and Communities. J Insect Conserv,2012:16:143-144.
24. R Core Team. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing, 2020.
25. Sonwa DJ, Nkongmeneck BA, Weise S, Tchatat M, Adesina A, Janssens MJJ. Diversity of plants in cocoa agroforests in the humid forest zone of Southern Cameroon. Biodivers Conserv,2007:16:2385-2400.
26. Tamesse JB, Messi J. Facteurs influençant la dynamique des populations du psylle africain des agrumes Trioza erythreae Del Guercio (Hemiptera: Triozidae) au Cameroun. Int J Trop Insect Sci,2004:24(3):213-227.
27. Tofangsazi N, Kheradmand K, Shahrokhi S, Talebi AA. Temperature-dependent life history of Schizaphis graminum on barley. Bull Insectol,2010:63(1):79-84.
28. Turpeau-Ait EL, Dedryver CA, Chaubet B, Hulle M. Pucerons des grandes cultures,1ère édition, ACTA, Paris, 2011, 135.
29. Van Emden HF, Bashford MA. The performance of Brevicoryne brassicae and Myzus persicae in relation to plant age and leaf amino-acids. Entomol Exp Appl,1971:14(3):349-360.
30. Van Emden HF. Insect and secondary plant substances: an alternative viewpoint with special reference to aphids. In: Harborne JB, editor. Biochemical aspects of plant and animal coevolution. London: Academic Press, 1978, 309-326.
31. Wolda H. Insect seasonality: Why? Annu Rev Ecol Syst,1988:19:1-18.
32. Yede B, Babin R, Djieto CL, Cilas C, Dibog L, Mahob R, Bilong BCF. True bug (Heteroptera) impact on cocoa fruit mortality and productivity. J Econ Entomol,2012:105:1285-1292.
33. Yede. Diversité des peuplements des hémiptères dans les cacaoyères de la région du Centre Cameroun: impact économique et essai de lutte biologique. Thèse de doctorat Ph.D, Université de Yaoundé I, Cameroun, 2016, 174.
34. Yede B, Mballa NPA, Tadu Z, Bilong BCF. Diversity and structure of ant communities associated with Toxoptera aurantii (Boyer, 1941) (Hemiptera, Aphididae) in cocoa farms in the Centre Region of Cameroon: Role of anthropogenic activities. J Biodivers Environ Sci,2023:23(3):139-151.
35. Yede B, Mahob RJ, Mbenoun MPS, Mballa NPA, Bilong BCF. Assessment of the impact of different developmental stages of Sahlbergella singularis Hagl. (Hemiptera: Miridae) on cacao trees productivity and fruits growth under field conditions in the Centre Region of Cameroon (Central Africa). Int J Adv Res,2024:12(3):735-744.