Journal of Agricultural Chemistry and Environment, 2026, 15(2), 129-140
https://www.scirp.org/journal/jacen
ISSN Online: 2325-744X
ISSN Print: 2325-7458

Diversity, Abundance, and Population Dynamics of Tephritid Fruit Flies in Mango Orchards across Agro-Ecological Zones of the Gambia during the Cool-Dry Season

Ismaila Mbenga[1,2*], Antonio Alain Coffi Sinzogan[3], Nasirou Sowe[2], Lamin Barrow[2], Jainaba Dampha[2]

[1]National Nanfan Research Institute (Sanya), Chinese Academy of Agricultural Science, Sanya, China
[2]National Agricultural Research Institute (NARI), Serekunda, The Gambia
[3]Faculte des Sciences Agronomiques, Universite d'Abomey Calavi, Cotonou, Benin
Email: *mbengisha@yahoo.com

How to cite this paper: Mbenga, I., Sinzogan, A.A.C., Sowe, N., Barrow, L. and Dampha, J. (2026) Diversity, Abundance, and Population Dynamics of Tephritid Fruit Flies in Mango Orchards across Agro-Ecological Zones of the Gambia during the Cool-Dry Season. *Journal of Agricultural Chemistry and Environment*, **15**, 129-140.
https://doi.org/10.4236/jacen.2026.152008

Received: February 25, 2026
Accepted: April 27, 2026
Published: April 30, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

Fruit flies (Diptera: Tephritidae) constitute one of the most destructive pest groups affecting mango production in West Africa. Despite their economic importance, baseline ecological information on fruit fly diversity and seasonal population dynamics in The Gambia remains scarce. This study assessed fruit fly species diversity, abundance, temporal fluctuations, trap efficiency and sex ratio dynamics across three agro-ecological zones of The Gambia during the dry and relatively cool season (January-February 2025). Using Torula yeast-baited traps deployed over a 45-day period, fruit fly populations were monitored weekly in mango orchards located in the Sahelian, Sudan Guinea, and Sudan Sahelian zones. A total of four tephritid species were recorded, with *Ceratitis cosyra* emerging as the dominant species across all zones. Fruit fly abundance peaked during Week 3 before declining, indicating strong temporal structuring even during the dry season. Trap efficiency (flies per trap per day, FTD) varied across zones, with the highest mean value recorded in the Sahelian Zone, whiles trap catches were male-biased throughout the study period. Fruit incubation tests confirmed active infestation despite the dry season. The results provide critical baseline data for phytosanitary surveillance and support the adoption of Integrated Pest Management (IPM) strategies for sustainable fruit fly control in The Gambia.

Keywords

Tephritidae, *Ceratitis cosyra*, Mango, Torula Yeast, IPM

1. Introduction

Fruit and vegetable production represents a major pillar of agricultural development in Africa, contributing significantly to income generation, employment, and food security [1]. Among fruit crops, mango (*Mangifera indica* L.) occupies a particularly prominent position in West Africa, where annual production exceeded one million tons in 2021 [2]. Africa accounts for about 4% of global mango production, with major producers including Burkina Faso, the Ivory Coast, Mali, Mozambique, Senegal, and South Africa; meanwhile, The Gambia exports mangoes to European Union markets, Maghreb countries, and Asia, reflecting its role in regional trade [3] [4]. Despite this importance, mango production and export potential in West Africa remain severely constrained by fruit fly infestations (Diptera: Tephritidae). Yield losses attributed to fruit flies range from 60% - 80%, primarily due to direct fruit damage and phytosanitary rejection [5] [6]. The invasion and spread of *Bactrocera dorsalis* have intensified these impacts, although native species such *as Ceratitis cosyra* remain ecologically dominant in many mango-growing systems [1] [7]. In The Gambia, systematic ecological data on fruit fly diversity, abundance, and seasonal dynamics are limited. Existing monitoring efforts have focused largely on the rainy season, leaving a critical knowledge gap regarding fruit fly behavior during the dry and cooler period, when mango fruiting often overlaps with export windows. Understanding fruit fly persistence during the dry season is essential for designing year-round IPM and phytosanitary surveillance programs.

Within this context, the SyRIMAO Project promotes environmentally sustainable pest management approaches, including the use of Torula yeast protein bait as a monitoring and control tool. Protein-based attractants offer a safer alternative to chemical insecticides, reducing environmental contamination, resistance development, and residue risks. It has been widely validated for fruit fly monitoring and suppression, demonstrating high attractiveness to both male and female tephritids while minimizing environmental and human health risks [8] [9].

Building on this foundation, the present study was designed to assess fruit fly species diversity and dominance across major agro-ecological zones of The Gambia during the cool-dry season, analyze spatial and temporal variation in fruit fly abundance, and evaluate trap efficiency using flies per trap per day (FTD). In addition, the study aimed to examine sex ratio dynamics, confirm infestation levels through fruit incubation tests. Together, these objectives provide a comprehensive framework for understanding fruit fly ecology and improving integrated pest management strategies under Gambian conditions.

2. Materials and Methods

2.1. Study Area and Orchard Selection

The study was conducted across three major agro-ecological zones of The Gambia, which served as the study sites: the Sahelian, Sudan Guinea, and Sudan Sahelian zones. The Sahelian zone, located in the northern part of the country, is relatively dry, while the Sudan Guinea zone in the south is more humid. The Sudan-Sahelian zone, situated between the two, experiences intermediate climatic conditions [10] [11]. Within each zone, three mango orchards were selected, giving a total of nine orchards. Orchard selection was based on the following criteria: 1) presence of actively fruiting mango trees during the study period, 2) orchard size ranging between 1 - 1.5 ha, 3) accessibility for regular monitoring, and 4) no recent insecticide application to avoid interference with fruit fly populations.

The orchards consisted predominantly of improved mango cultivars, although some sites included a mixture of local and improved varieties. All selected orchards were at comparable phenological stages, characterized by the presence of mature to ripening fruits during the sampling period (January-February 2025), which is known to be highly susceptible to fruit fly infestation. Management practices varied slightly among orchards but generally reflected low-input production systems typical of The Gambia, where pesticide use was absent, systematic fruit sanitation was not practiced, and no irrigation systems were in place.

2.2. Trapping Design and Baiting

A total of nine McPhail traps per agro-ecological zone were deployed, with three traps installed in each of three orchards per zone. Traps were baited with four Torula yeast (Protein based attractant) pellets and suspended within the mango tree canopy at approximately mid-canopy height. Traps were placed within 50 meters of each other in each orchard and monitoring was conducted over a period of 45 days (six consecutive weeks), with traps inspected and serviced at weekly intervals.

2.3. Sample Collection and Processing

Sampling was conducted over a six-week period corresponding to the cooler dry season, which is characterized by reduced host availability and relatively stable climatic conditions. This period is ecologically relevant for assessing baseline fruit fly diversity, persistence, and early population build-up prior to the onset of the rainy season. The primary sampling unit (replicate) was the orchard, while traps within each orchard were treated as subsamples. Traps were inspected weekly, and captured fruit flies were collected and preserved in 70% ethanol. Each sample was labeled with the agro-ecological zone, orchard, trap number, and collection date. Specimens were subsequently transported to the Pest Management Laboratory of the National Agricultural Research Institute (NARI) for sorting and identification.

2.4. Species Identification and Sex Determination

Fruit fly specimens were identified morphologically to species level using standard taxonomic keys, including those developed under the SyRIMAO Project, the identification guide by [1], and the online database True Fruit Flies of the Afrotropical Region developed by [12]. Identification was based on diagnostic morphological characteristics such as wing patterns, thoracic markings, and abdominal features.

However, specimens belonging to the genus *Zeugodacus* were identified only to genus level due to the lack of clear and consistent diagnostic morphological features required for reliable species-level separation under the conditions of this study. In particular, closely related species within this genus exhibit overlapping morphological traits, and accurate identification often requires detailed morphometric or molecular analyses, which were beyond the scope of this study.

2.5. Incubation Test

To validate trap capture data and confirm active infestation, an incubation test was conducted. In each orchard, five mango trees were randomly selected, and five infested fruits per tree were collected. Fruits were incubated under controlled laboratory conditions until adult emergence, allowing confirmation of species presence and infestation status.

2.6. Data Collection and Analysis

Data were summarized using descriptive statistics, including means, proportions, and graphical representations, without the application of inferential statistical tests. Fruit fly abundance, trap efficiency, and sex ratio patterns were compared across agro-ecological zones and sampling weeks using trends and visual interpretation. Species diversity was assessed using Shannon-Wiener (H') and Simpson's indices.

Trap efficiency was calculated as flies per trap per day (FTD) using the formula:

$$\text{FTD} = \frac{Total\ Number\ of\ Flies\ Captured}{Number\ of\ traps \times Number of\ Exposuredays}$$

3. Results and Discussion

In this study, differences among agro-ecological zones and sampling weeks were analyzed descriptively, with interpretations based on observed trends.

3.1. Species Composition and Relative Abundance

A total of four tephritid fruit fly species were recorded across all agro-ecological zones during the dry and cooler season (January-February). These species were *C. cosyra*, *B. dorsalis, Zeugodacus spp*., and *Dacus vertebratus* (**Figure 1**).

Ceratitis cosyra was the dominant species across all agro-ecological zones, accounting for the highest proportion of fruit fly captures, followed by *B. dorsalis*. *Zeugodacus* spp. and *D. vertebratus* occurred at consistently low frequencies throughout the study period (**Figure 1**). Overall, species composition was broadly similar among zones; however, slight variations in relative abundance were observed, likely reflecting differences in orchard conditions and host availability.

The dominance of *C. cosyra* during the dry season observed in this study is consistent with its well-documented ecological adaptability and strong association with mango, as well as a range of alternative wild hosts. Previous studies in West

Africa have shown that *C. cosyra* populations often peak during the dry season, particularly at the early stages of mango fruiting, reflecting its tolerance to relatively dry conditions and its ability to exploit both cultivated and wild host plants when primary hosts are limited [13] [14]. The availability of alternative hosts in surrounding vegetation has been identified as a key factor supporting the persistence and dominance of *C. cosyra* outside peak mango production periods [1] [13].

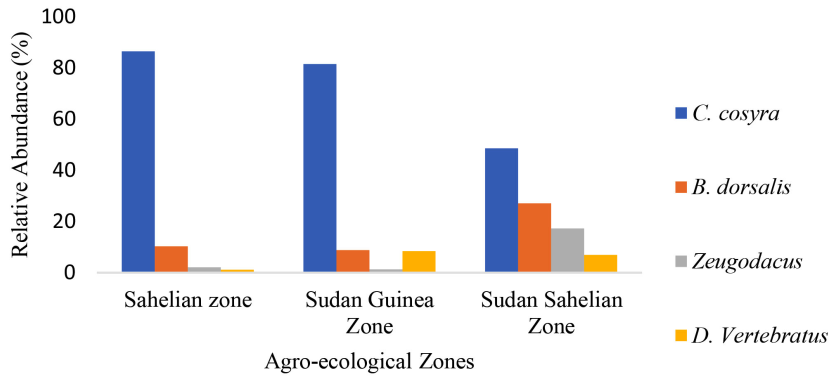

Figure 1. Species composition of fruit flies captured in mango orchards across the three agro-ecological zones of The Gambia.

In contrast, the presence of *B. dorsalis* at moderate levels during the dry season suggests its ability to persist under less favorable climatic conditions, potentially functioning as a reservoir population for subsequent rainy-season outbreaks. Although *B. dorsalis* typically reaches its highest abundance during the rainy season in response to increased host availability and favorable humidity, several studies have demonstrated its year-round presence sustained by alternative cultivated and wild hosts in orchard-adjacent landscapes [13] [15]. Such persistence enables rapid population buildup once climatic conditions and host availability improve, highlighting the contrasting seasonal population strategies of *C. cosyra* and *B. dorsalis* and their implications for integrated fruit fly management in mango-growing systems.

3.2. Temporal Population Fluctuation

Fruit fly populations exhibited clear spatial and temporal variation across the three agro-ecological zones during the six-week monitoring period within the cool dry season of The Gambia (**Figure 2**). The Sahelian Zone recorded relatively high populations at the onset of sampling, followed by a rapid decline and low population levels thereafter. In contrast, the Sudan Guinea Zone showed a sharp and well-defined population peak in week 3, representing the highest abundance recorded during the study. The Sudan Sahelian Zone consistently recorded the lowest fruit fly populations, with only minor fluctuations throughout the monitoring period.

The pronounced population peak observed in the Sudan Guinea Zone, despite the generally suppressive conditions of the cool dry season, may be partly explained by the higher concentration of commercially operated mango orchards in this zone. Commercial mango production systems provide continuous host availability, higher tree densities, and overlapping fruiting periods, which can sustain localized fruit fly populations even under sub-optimal climatic conditions. Similar findings have been reported in other West African and tropical systems, where host availability and orchard intensification override seasonal climatic constraints on fruit fly populations [14] [16].

The generally low fruit fly populations recorded in the Sudan Sahelian Zone may be due to the combined effects of limited commercial fruit production, lower host density, and the cooler, drier conditions prevailing during the study period, which are known to reduce fruit fly survival and reproductive rates [17].

Overall, these results suggest that while the cool dry season limits overall fruit fly abundance in The Gambia, commercial mango production areas particularly within the Sudan Guinea Zone remain vulnerable to localized population outbreaks. This underscores the importance of maintaining year-round surveillance and targeted management in high-risk production zones, even outside the main rainy season.

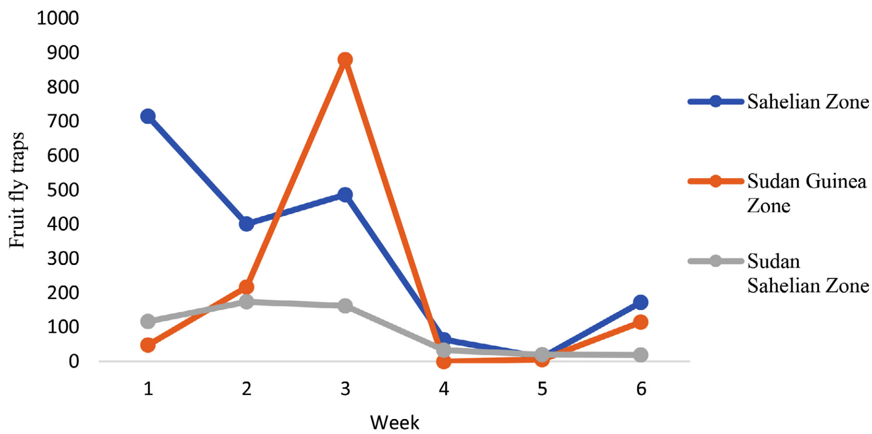

Figure 2. Weekly population fluctuation of fruit flies (Week 1 - 6) across agro-ecological zones during the dry season.

3.3. Spatial and Temporal Distribution Patterns

The heatmap revealed clear spatial and temporal heterogeneity in relative fruit fly abundance across the three agro-ecological zones of The Gambia during the cold dry season (**Figure 3**). A pronounced peak was observed in Week 3, particularly in the Sudan-Guinea zone, while comparatively lower to moderate levels were recorded in the Sahelian and Sudan-Sahelian zones. Although the cold dry season in The Gambia is characterized by no rainfall and Harmattan conditions, daytime temperatures remain within the optimal developmental range for major *Tephritidae* species. Population persistence and mid-season peaks during this period are therefore likely influenced by host fruit phenology and irrigated production systems than by rainfall alone. Similar dry-season persistence patterns have been reported across West Africa, where fruit fly abundance closely follows host availability rather than strictly seasonal rainfall trends [18] [19].

Spatially, the higher abundance observed in the Sudan-Guinea zone compared to the Sahelian belt may be associated with the north-south ecological gradient typical of West Africa, although environmental variables such as humidity, vegetation density, and host plant diversity were not directly measured in this study. Similar patterns have been reported in Senegal, Mali, and Burkina Faso, where greater fruit fly densities were documented in more humid Sudanian and Guinean zones compared to drier Sahelian regions [13] [20].

Similarly, more recent work in Ghana also highlighted that fruit fly hotspots coincided with areas of high orchard density and favorable microclimates, reinforcing the role of landscape and host phenology in structuring pest populations [15].

These findings suggest that fruit fly dynamics in The Gambia during the cold dry season may be structured by climate host interactions along agro-ecological gradients, with important implications for seasonally targeted surveillance and integrated pest management strategies.

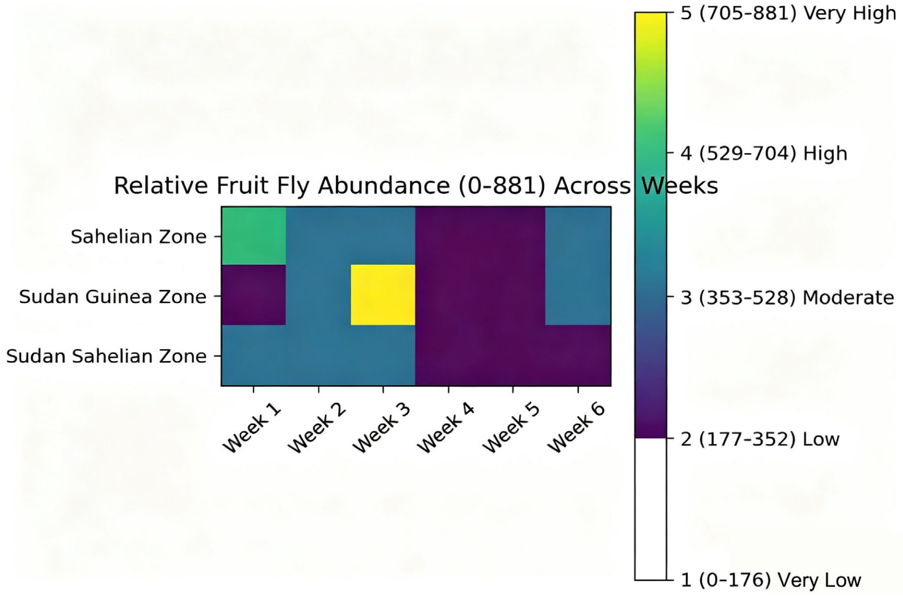

Figure 3. Heat map of fruit fly abundance by agro-ecological zone and sampling week.

3.4. Trap Efficiency (Flies Per Trap Per Day)

Trap efficiency, expressed as flies per trap per day (FTD), varied among zones but followed a similar temporal trend. The highest FTD values were recorded during the third week period, corresponding with peak population abundance (**Table 1**). Comparable findings have been reported in West Africa, where FTD values typically remain lower during cooler, drier periods compared to the rainy season, yet still provide reliable indicators of population dynamics [15].

Importantly, Torula yeast proved effective in attracting adult fruit flies across all ecological zones, confirming its suitability for surveillance and IPM-based monitoring during dry-cooler periods. Previous studies have validated protein-based attractants such as Torula yeast as efficient tools for monitoring both male and female tephritids, offering a safer alternative to chemical lures [9]

These results highlight that while absolute trap catches may be lower in the dry season, Torula yeast remains a robust attractant for ecological surveillance. Its effectiveness across diverse agro-ecological zones underscores its value for year-round monitoring programs in The Gambia, ensuring that pest management strategies are informed by reliable data even outside peak rainy-season activity.

Table 1. Trap efficiency (flies per trap per day) by agro-ecological zone and sampling week.

Sampling week	Sahelian Zone	Sudan Guinea Zone	Sudan Sahelian Zone
Week 1	1.76	0.12	0.29
Week 2	0.99	0.54	0.43
Week 3	1.20	2.18	0.40
Week 4	0.16	0.00	0.08
Week 5	0.03	0.01	0.05
Week 6	0.43	0.28	0.05
Mean FTD	0.76	0.52	0.22

3.5. Sex Ratio Dynamics

Sex ratio analysis revealed a consistent predominance of male fruit flies across all zones and sampling weeks. Male captures exceeded female captures throughout the study period, with Male proportions increasing during peak population weeks (**Figure 4**). This male-biased sex ratio is a well-documented outcome of protein-based attractants such as Torula yeast, which are particularly effective in luring reproductively active males. Similar findings have been reported in West African mango systems, where male captures consistently outnumber females under protein bait surveillance [6].

The strong male attraction underscores the utility of Torula yeast in integrated pest management (IPM) programs, both for population suppression and as an early warning surveillance tool. [9] demonstrated that protein-based lures provide reliable monitoring of male tephritids, offering a safer alternative to synthetic insecticides while minimizing environmental risks. More recent studies in Ghana and Benin confirmed that male biased captures are consistent across agro-ecological zones, reinforcing the robustness of protein baits for dry season monitoring [6] [15].

Collectively, these results highlight that while female captures remain comparatively lower, male biased sex ratios provide valuable indicators of fruit fly population dynamics. This strengthens the case for Torula yeast as a cornerstone of

IPM strategies, ensuring effective surveillance and timely interventions during critical fruiting periods.

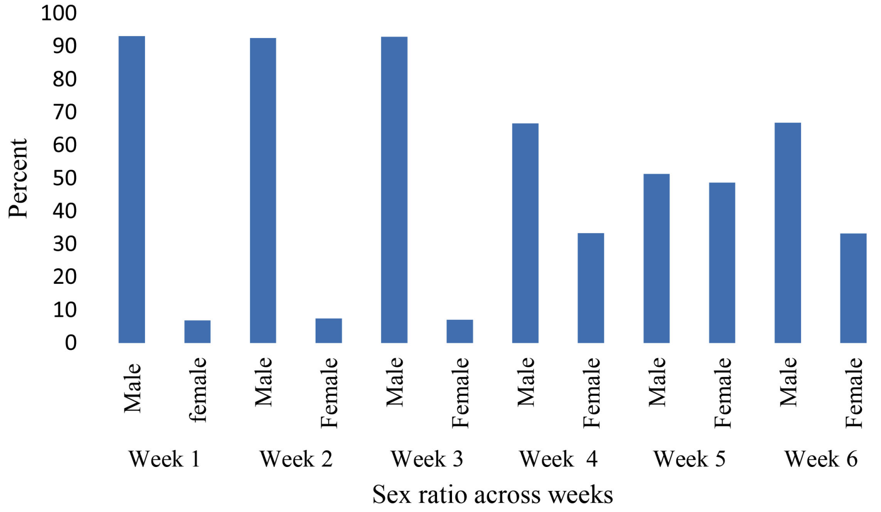

Figure 4. Parentage Sex ratio dynamics of fruit flies across sampling weeks during the dry season.

3.6. Diversity Indices

Species richness was uniform across all agro-ecological zones, with four species recorded in each zone. Shannon-Wiener diversity (H') values ranged from 1.05 to 1.19, indicating moderate diversity during the dry season (Table 2). The Sahelian Zone exhibited the highest diversity value, while the Sudan Guinea Zone showed lower diversity, reflecting stronger dominance by *C. cosyra*. Simpson's diversity indices further confirmed a moderately structured fruit fly community dominated by one principal species during the data collection period in The Gambia.

Comparable diversity patterns have been reported in other West African studies. [6] documented moderate Shannon diversity values in mango orchards in Benin, with *C. cosyra* often dominating communities despite the presence of invasive *B. dorsalis*. Similarly, [7] observed co-existence of *B. dorsalis* and *C. cosyra* in Burkina Faso, but noted that *C. cosyra* remained ecologically dominant in certain zones, leading to lower evenness values. In Ghana, [21] also reported moderate diversity indices, with species richness relatively uniform across orchards but community structure shaped by host phenology and local agro-ecological conditions.

These findings suggest that while species richness may remain stable across zones, diversity indices are sensitive to patterns of species dominance. The predominance of *C. cosyra* in the Sudan Guinea Zone during the study period underscores the role of dominance in shaping community structure. Such insights are critical for tailoring IPM strategies, as zones with lower diversity and stronger dominance may require more targeted interventions to manage the principal pest species effectively.

Table 2. Diversity indices of fruit fly assemblages across agro-ecological zones during the dry and cooler season.

Agro-ecological Zone	Species richness (S)	Shannon-Wiener (H')	Simpson's index (1-D)
Sahelian Zone	4	1.19	0.64
Sudan Sahelian Zone	4	1.12	0.61
Sudan Guinea Zone	4	1.05	0.58

3.7. Incubation Test Results

Incubation tests confirmed active fruit infestation across all agro-ecological zones during the dry season, with more than half of the incubated fruits producing adult fruit flies. Emergence rates were highest in the Sahelian Zone, reflecting localized abundance patterns observed in trap catches. *Ceratitis cosyra* accounted for the majority of emerged adults, corroborating trap-based observations of species dominance and reinforcing its role as the principal pest species in Gambian mango systems during cool dry season (**Table 3**).

Comparable findings have been reported across West Africa. [7] observed that while *B. dorsalis* has expanded its range in Burkina Faso, *C. cosyra* remained ecologically dominant in mango orchards, particularly in zones with lower rainfall. More recent work in Ghana also highlighted that incubation tests consistently revealed high infestation levels during fruiting stages, with *C. cosyra* emerging as the abundant species [22].

These results emphasize the importance of combining trap-based monitoring with fruit incubation assays to confirm species dominance and infestation pressure. The predominance of *C. cosyra* across zones underscores its continued ecological significance, while the high emergence rates highlight the persistent risk of fruit damage even during dry-season production.

Table 3. Results of fruit incubation tests confirming fruit fly infestation in mango orchards across agro-ecological zones during the dry and cooler season in The Gambia.

Agro-ecological zone	Fruits incubated (n)	Fruits with adult emergence (%)	Mean adults emerged per fruit	Dominant species emerged
Sahelian Zone	75	68.0	3.6	*C. cosyra*
Sudan Sahelian Zone	75	61.3	3.1	*C. cosyra*
Sudan Guinea Zone	75	54.7	2.7	*C. cosyra*
Overall mean	225	61.3	3.1	*C. cosyra*

4. Conclusion

This study provides the first detailed assessment of fruit fly diversity and population dynamics during the dry and cooler season in The Gambia. The findings underscore the importance of dry-season surveillance for effective integrated pest management and offer baseline data for future seasonal comparisons.

5. Limitation

While longer-term monitoring would provide additional insights into annual population dynamics, the present study provides robust baseline information for the cool-dry season, a critical yet understudied period for early intervention planning in fruit fly management

Acknowledgements

The authors express appreciation to the SyRIMAO/ECOWAS Project for funding this research.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ekesi, S. and Billah, M.K. (2006) A Field Guide to the Management of Economically Important Tephritid Fruit Flies in Africa. International Centre of Insect Physiology and Ecology (ICIPE).

[2] Direction de la Protection des Végétaux (DPV) and SyRIMAO Project (2021) Mango Production and Export Statistics for West Africa (Data Compilation Report). DPV-SyRIMAO.

[3] Food and Agriculture Organization of the United Nations (FAO) (2022) FAOSTAT Statistical Database. https://www.fao.org/faostat/

[4] International Trade Centre (ITC) (2022) Trade Statistics and Market Analysis for Mango Exports from West Africa. ITC.

[5] Ndiaye, O., Vayssieres, J., Yves Rey, J., Ndiaye, S., Diedhiou, P.M., Ba, C.T., *et al.* (2012) Seasonality and Range of Fruit Fly (diptera: Tephritidae) Host Plants in Orchards in Niayes and the Thiès Plateau (Senegal). *Fruits*, **67**, 311-331. https://doi.org/10.1051/fruits/2012024

[6] Vayssières, J.F., De Meyer, M., Ouagoussounon, I., Sinzogan, A., Adandonon, A., Korie, S., *et al.* (2015) Seasonal Abundance of Mango Fruit Flies (Diptera: Tephritidae) and Ecological Implications for Their Management in Mango and Cashew Orchards in Benin (Centre & North). *Journal of Economic Entomology*, **108**, 2213-2230. https://doi.org/10.1093/jee/tov143

[7] Zida, I., Nacro, S., Dabiré, R. and Somda, I. (2020) Co-Existence of *Bactrocera dorsalis* Hendel (Diptera: Tephritidae) and *Ceratitis cosyra* Walker (Diptera: Tephritidae) in the Mango Orchards in Western Burkina Faso. *Advances in Entomology*, **08**, 46-55. https://doi.org/10.4236/ae.2020.81004

[8] Epsky, N.D., Hendrichs, J., Katsoyannos, B.I., Vásquez, L.A., Ros, J.P., Zümreoglu, A., *et al.* (1999) Field Evaluation of Female-Targeted Trapping Systems for *Ceratitis capitata* (Diptera: Tephritidae) in Seven Countries. *Journal of Economic Entomology*, **92**, 156-164. https://doi.org/10.1093/jee/92.1.156

[9] Heath, R.R., Epsky, N.D., Dueben, B.D., Rizzo, J. and Jeronimo, F. (1997) Adding Methyl-Substituted Ammonia Derivatives to a Food-Based Synthetic Attractant on Capture of the Mediterranean and Mexican Fruit Flies (Diptera: Tephritidae). *Journal of Economic Entomology*, **90**, 1584-1589. https://doi.org/10.1093/jee/90.6.1584

[10] United Nations Framework Convention on Climate Change (UNFCCC) (2020) Climate

Resilience in The Gambia: Case Study on Agro-Ecological Zones and Adaptation Strategies. https://unfccc.int/sites/default/files/resource/crfs_gambia_casestudy.pdf

[11] Nooni, I.K., Ogou, F.K., Saidou Chaibou, A.A., Fianko, S.K., Atta-Darkwa, T. and Prempeh, N.A. (2025) Relative Humidity and Air Temperature Characteristics and Their Drivers in Africa Tropics. *Atmosphere*, **16**, Article 828. https://doi.org/10.3390/atmos16070828

[12] De Meyer, M. and White, I.M. (2004) True Fruit Flies (Diptera: Tephritidae) of the Afrotropical Region Database. Royal Museum for Central Africa. http://projects.bebif.be/fruitfly/

[13] Vayssières, J.F., Rey, J.Y., Traoré, L. and Diarra, K. (2009) Seasonal Abundance of Mango Fruit Flies (Diptera: Tephritidae) in West Africa: Effects of Host Phenology and Weather. *Fruits*, **64**, 361-373.

[14] Ekesi, S., De Meyer, M., Mohamed, S.A., Virgilio, M. and Borgemeister, C. (2016) Taxonomy, Ecology, and Management of Native and Exotic Fruit Fly Species in Africa. *Annual Review of Entomology*, **61**, 219-238. https://doi.org/10.1146/annurev-ento-010715-023603

[15] Ofori, E.S.K., Osae, M.Y., Kwapong, P.K. and Abraham, J. (2023) Population Dynamics of Fruit Flies (Diptera: Tephritidae) in Mango Orchards in the Southeastern Mango Enclave of Ghana. *International Journal of Tropical Insect Science*, **43**, 2201-2213. https://doi.org/10.1007/s42690-023-01116-1

[16] Vayssières, J.F., Rey, J.Y., Traoré, L. and Diarra, K. (2008) Distribution and Host Plants of Fruit Flies (Diptera: Tephritidae) in West Africa. *Fruits*, **63**, 363-371.

[17] Rwomushana, I., Ekesi, S., Gordon, I. and Ogol, C.K.P.O. (2008) Host Plants and Host Plant Preference Studies for *Bactrocera invadens* (Diptera: Tephritidae) in Kenya, a New Invasive Fruit Fly Species in Africa. *Annals of the Entomological Society of America*, **101**, 331-340. https://doi.org/10.1603/0013-8746(2008)101[331:hpahpp]2.0.co;2

[18] Vayssières, J., Goergen, G., Lokossou, O., Dossa, P. and Akponon, C. (2005) A New *Bactrocera* Species in Benin among Mango Fruit Fly (Diptera: Tephritidae) Species. *Fruits*, **60**, 371-377. https://doi.org/10.1051/fruits:2005042

[19] Ekesi, S., Billah, M.K., Nderitu, P.W., Lux, S.A. and Rwomushana, I. (2009) Evidence for Competitive Displacement of *Ceratitis cosyra* by the Invasive Fruit Fly *Bactrocera invadens* (Diptera: Tephritidae) on Mango and Mechanisms Contributing to the Displacement. *Journal of Economic Entomology*, **102**, 981-991. https://doi.org/10.1603/029.102.0317

[20] Badii, K.B., Billah, M.K., Afreh-Nuamah, K. and Obeng-Ofori, D. (2015) Species Composition and Host Range of Fruit-Infesting Flies (Diptera: Tephritidae) in Northern Ghana. *International Journal of Tropical Insect Science*, **35**, 137-151. https://doi.org/10.1017/s1742758415000090

[21] Awarikabey, E.N., Afun, J.V.K., Billah, M.K. and Osekre, E.A. (2025) Diversity, Damage and Pheromone Specificity of Fruit Flies in the Forest-Savanna Transition Zone of Ghana. *Bulletin of Entomological Research*, **115**, 155-165. https://doi.org/10.1017/s0007485324000750

[22] Billah, M.K., Oyinkah, G.M., Badii, B.K. and Cobblah, M.A. (2023) A Safe Haven or a Temporary Alternative Host? The Displaced Mango Fruit Fly, *Ceratitis cosyra*, in the African Peach Plant. *West African Journal of Applied Ecology*, **31**, 56-63.