

The Impact of Viroid-Induced Diseases: The Need for Vigilance in Nigeria Amid Climate Change

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ABSTRACT

Viroids are small, non-coding RNA pathogens that pose significant threats to global agriculture, affecting a wide range of economically-important crops. In Nigeria, the impact of viroid-induced diseases is a growing concern, particularly amid changing climatic conditions as there is virtually no any effort made to uncover the presence of viroids. Viroids, such as *Potato spindle tuber viroid* (PSTVd), *Avocado sunblotch viroid* (ASBVd), and *Citrus exocortis viroid* (CEVd), are globally distributed and have severe economic repercussions. Despite their widespread presence, there is a notable dearth of research on viroids in Nigeria, leaving the country's agricultural sector vulnerable. Viroids induce a variety of symptoms, including stunted growth, chlorosis, and fruit deformities, leading to significant yield losses. Transmission occurs through mechanical damage, vegetative propagation, seed transmission, and insect vectors. Effective management involves stringent phytosanitary measures; early detection through molecular techniques like RT-PCR, and regulatory controls to prevent spread. This review highlights the urgent need for increased research and vigilance in Nigeria to address the threats posed by viroids. Enhanced monitoring, early detection, and international collaboration are essential for developing comprehensive management strategies. Addressing these gaps is crucial for safeguarding Nigeria's agricultural productivity and ensuring food security in the face of climate change.

Keywords: Viroid, impact, Nigeria, detection, management, plant

1.0 INTRODUCTION

Plant viroids are single-stranded, circular RNA molecules that are the smallest known infectious diseases and can cause major economic losses to crops (Carbonell, 2022). Viroids belong to the family *Pospiviroidae* and *Avsunviroidae* (Srivastava & Prasad 2020; Wang, 2021; Fuji *et al.*, 2022) and could cause significant economic losses on ornamentals and other crops (Hassan and Golino, 2019; Gautam *et al.*, 2021). Despite their profound impact, the research on plant viroids within Nigeria remains conspicuously sparse. In stark contrast, other plant pests and diseases are well-documented in Nigeria. For example, Cassava Mosaic Disease (CMD), caused by the *Cassava mosaic virus* (CMV), significantly impacts cassava production (Eni *et al.*, 2021; Igwe *et al.*, 2021; Chikoti & Tembo, 2022). *Maize streak virus* (MSV) also poses a severe threat to maize crops, one of Nigeria's staple foods (Emeraghi *et al.*, 2021). The fungal disease black sigatoka, affecting banana and plantain crops, is another well-researched area due to its devastating effects on yields (Reay, 2019). This dearth of scientific inquiry is particularly concerning in the context of climate change, which is expected to exacerbate plant disease dynamics and crop vulnerabilities (Hunjan & Lore, 2020; Jeger, 2022; Singh *et al.*, 2023). It is noteworthy to mention recently findings of three viroids associated with grapes in Nigeria; *Hop stunt viroid* (HSVd), *Grapevine yellow speckle viroid 1* (GYSVd-1),

and *Grapevine yellow speckle viroid 2* (GYSVd-2) (Zangoma *et al.*, 2018; 2023). Aside from these studies, not much focused work has been done to find viroids associated to our staple crops in particular and ornamentals. As Nigeria faces increasing challenges related to food security and agricultural sustainability, understanding and addressing the gaps in viroid research is crucial. This paper explores the current state of knowledge regarding plant viroids in Nigeria, highlights the critical gaps, and underscores the urgency of integrating viroid research into broader agricultural and climate resilience strategies (Scholthof *et al.*, 2011). By illuminating these deficiencies, we aim to stimulate focused research efforts and policy interventions that can safeguard Nigeria's agricultural future in an era of climatic uncertainty. This paper aims therefore, at invigorating a directed and concerted research focus towards the identification and characterization of viroids associated with agricultural and ornamental crops in Nigeria amid climate change for sustainable crop production.

1.1 What Are Viroids?

Viroids are the smallest known infectious pathogens, consisting solely of a short strand of circular, single-stranded RNA (246 to 401 nucleotides) without any protein coat. Unlike viruses, viroids do not encode proteins, and their pathogenicity is primarily attributed to

their RNA structure and its interaction with the host's cellular machinery (Flores *et al.*, 2014; Shrestha & Bujarski 2020; Navarro *et al.*, 2021; Ramesh *et al.*, 2021). These tiny RNA molecules, typically 246 to 401 nucleotides in length, rely entirely on the host plant for replication and propagation, making them obligate parasites (Wu *et al.*, 2019; Shrestha & Bujarski, 2020; Singhal *et al.*, 2021). Viroids cause disease by hijacking the host's cellular processes, leading to a range of symptoms that include stunted growth, leaf curling, and necrosis (Bozbuga *et al.*, 2022; Wang *et al.*, 2022). The mechanisms by which viroids induce these symptoms are not entirely understood, but it is believed that they interfere with the host's RNA silencing pathways, a critical component of the plant's defense mechanism against pathogens (Di Serio *et al.*, 2017; Ramesh *et al.*, 2021; Kryovrysanaki *et al.*, 2021; Wang *et al.*, 2022). This interference results in the disruption of normal plant development and physiology, causing significant agricultural damage. Despite their simple structure, viroids are remarkably resilient and can spread rapidly through mechanical means, such as contaminated tools, vegetative propagation, and possibly insect vectors (Flores *et al.*, 2014; Koshariya *et al.*, 2023). Their impact on agriculture is substantial, particularly in crops like potatoes, tomatoes, and hops, where viroid infections can lead to severe yield losses (Hadidi *et al.*, 2017; Harish *et al.*, 2021).

1.2 Composition of Plant Viroids

Plant viroids are the smallest infectious pathogens, consisting solely of a circular, single-stranded RNA molecule ranging from 246 to 401 nucleotides in length. Unlike viruses, viroids lack a protein coat and do not encode proteins, relying entirely on host plant machinery for replication and propagation (Flores *et al.*, 2014; Dongre *et al.*, 2023; Koshariya *et al.*, 2023). Their RNA genome is divided into structural domains: the central conserved region (CCR), pathogenicity domain, variable domain, and terminal domains, each playing specific roles in replication and pathogenicity (Di Serio *et al.*, 2017; Adkar-Purushothama & Perreault 2020; Sano, 2021; Navarro *et al.*, 2021). The CCR is crucial for replication, involving the processing of the RNA genome into its circular form (Wang 2021; Ortolá & Daròs, 2023). Viroid RNA forms stable secondary structures, such as rod-like or branched conformations, which protect it from degradation and facilitate interactions with host proteins (Flores *et al.*, 2014; Navarro *et al.*, 2021). Replication occurs in the host's nucleus or chloroplasts, depending on the viroid species, following a rolling-circle mechanism that produces multimeric intermediates processed into monomeric circular forms (Navarro *et al.*, 2021; Wang, 2021). This process relies

on the host's RNA polymerases since viroids do not encode their own enzymes (Navarro *et al.*, 2012).

2.0 TAXONOMY/CLASSIFICATION OF PLANT VIROIDS

Viroids belong to the family *Pospiviroidae* and *Avsunviroidae*. *Pospiviroidae* includes genera like *Pospiviroid*, *Hostuviroid*, *Cocadviroid*, *Apscaviroid*, and *Coleviroid*, primarily replicating in the nucleus. *Avsunviroidae* includes genera such as *Avsunviroid*, *Pelamoviroid*, and *Elaviroid*, replicating in the chloroplasts (Di Serio *et al.*, 2017; Bajdek, 2019; Flores *et al.*, 2021). Unlike viruses, viroids lack a protein coat and do not encode proteins, relying on the host's cellular machinery for replication and spread (Flores *et al.*, 2014; Moelling & Broecker 2021; Sidhant & Soumen 2022). Their classification is based on structural features, mode of replication, and pathogenicity.

2.1 Symptoms of Plant Viroids Infection

Viroid infections in plants cause a range of symptoms, including stunted growth, leaf curling, chlorosis, necrosis, and distorted fruit development. These symptoms result from the viroid's interference with the host plant's RNA silencing pathways, disrupting normal physiological processes (Flores *et al.*, 2020; Di Serio *et al.*, 2023). Severity of symptoms can vary depending on the viroid species and the host plant, with some infections leading to significant yield losses (Flores *et al.*, 2014; Adkar-Purushothama & Perreault, 2020; Bozbuga *et al.*, 2022). Infected plants often exhibit a decrease in vigor and productivity, severely impacting on agricultural output (Gozmanova *et al.*, 2020). Specific viroids, such as *Potato spindle tuber viroid* (PSTVd), are known to cause severe disease symptoms in solanaceous crops (Tsushima *et al.*, 2015).

2.2 Hosts Infected by Viroids

Viroids infect a wide range of plant hosts, including both monocotyledonous and dicotyledonous species. Key agricultural crops affected by viroids include potatoes, tomatoes, cucumbers, citrus, avocados, hops, and various ornamentals such as chrysanthemums and dahlias (Flores *et al.*, 2014; Flores *et al.*, 2021). *Potato spindle tuber viroid* (PSTVd) is particularly notorious for infecting solanaceous crops like potatoes and tomatoes, causing severe yield losses (Tsushima *et al.*, 2015). *Avocado sunblotch viroid* (ASBVd) significantly impacts avocado production by reducing fruit quality and yield (Flores *et al.*, 2014). *Citrus exocortis viroid* (CEVd) and *Hop latent viroid* (HLVd) infect citrus and hops, respectively, leading to stunted growth and reduced productivity (Owens *et al.*, 2012; Hagemann *et al.*, 2023). *Coconut cadang-cadang viroid* (CCCVd) infects coconut and oil palms, causing a lethal disease that severely affects trees

health and productivity (Štajner *et al.*, 2019; Flores *et al.*, 2021). Viroids also infect ornamental plants, leading to economic losses in horticulture (Hassan and Golino, 2019). The wide host range of viroids underscores their adaptability and the potential threat they pose to diverse agricultural systems.

2.3 Transmission of Viroids

Viroids are transmitted through several mechanisms, including mechanical means, vegetative propagation, and seed transmission (Zhou *et al.*, 2020; Hammond, 2024). Mechanical transmission occurs through contaminated tools, such as pruning shears, and human activities that cause plant wounding (Flores *et al.*, 2014; Koshariya *et al.*, 2023). Vegetative propagation, involving grafting or the use of infected cuttings, is a significant pathway for viroid spread in crops like potatoes, citrus, and avocados (Hadidi *et al.*, 2022). Seed transmission is another important route, with some viroids being transmitted from infected parent plants to their progeny through seeds. This method has been documented in crops like tomatoes and potatoes (Ding and Wang, 2015; Nallathambi *et al.*, 2020). Additionally, viroids can be spread by insect vectors, such as aphids and thrips, which facilitate their movement between plants (Catto *et al.*, 2022; Arpaci *et al.*, 2024). Viroids can also be disseminated through natural means like wind and water, which carry infected plant debris to new locations, further enhancing their spread and persistence in agricultural environments (Flores *et al.*, 2014; Koshariya *et al.*, 2023).

2.4 Economic Importance of Viroids

Viroids pose significant economic threats to agriculture due to their ability to infect a wide range of important crops (Nazarov *et al.*, 2020; Hadidi *et al.*, 2020), leading to reduced yields, poor quality produce, and increased management costs. Infected plants often exhibit symptoms such as stunted growth, chlorosis, and malformed fruits, directly impacting marketability and profitability (Flores *et al.*, 2014; Venkataraman *et al.*, 2024). For instance, *Potato spindle tuber viroid* (PSTVd) can severely reduce potato and tomato yields, while *Avocado sunblotch viroid* (ASBVd) affects both yield and fruit quality in avocados (Tsushima *et al.*, 2015; Aviña-Padilla *et al.*, 2022). In the citrus industry, *Citrus exocortis viroid* (CEVd) leads to reduced tree vigor and fruit yield, necessitating costly management practices (Reanwarakorn and Dollet, 2016; da Graça & Kunta, 2022; Bar-Joseph *et al.*, 2023). Similarly, *Coconut cadang-cadang viroid* (CCCVd) in oil palms and coconuts causes significant crop losses, threatening livelihoods and the economy (Vadamalai *et al.*, 2024). The ornamental plant industry also suffers economic losses due to viroid infections, as affected plants often

lose their aesthetic value, leading to decreased sales (Hassan and Golino, 2019). Overall, viroids require stringent phytosanitary measures and continuous monitoring to prevent their spread and mitigate economic impacts.

2.5 Detection of Viroids

The detection of viroids is crucial for managing and preventing their spread in agricultural systems (Jones & Naidu, 2019). Traditional detection methods include biological indexing, where susceptible indicator plants are inoculated and observed for symptoms, a time-consuming but effective approach (Navarro *et al.*, 2012). However, Modern molecular techniques have significantly improved viroid detection (Hadidi, 2019; Adkar-Purushothama & Perreault, 2020). Reverse transcription-polymerase chain reaction (RT-PCR) is the most commonly used method due to its high sensitivity and specificity (Guček *et al.*, 2019; Singhal *et al.*, 2021). This technique involves reverse transcribing viroid RNA into complementary DNA (cDNA) followed by amplification using specific primers (Hadidi *et al.*, 2013). Real-time RT-PCR (qRT-PCR) further enhances detection by quantifying viroid RNA levels in real-time, providing both qualitative and quantitative data (Matsushita *et al.*, 2011). Next-generation sequencing (NGS) offers comprehensive viroid detection and characterization, allowing for the identification of known and novel viroids in complex samples (Massart *et al.*, 2014; Hadidi, 2019; Singhal *et al.*, 2021). Additionally, loop-mediated isothermal amplification (LAMP) is emerging as a rapid, cost-effective alternative for field diagnostics, capable of detecting viroids without the need for sophisticated laboratory equipment (Nie and Singh, 2017; Panno *et al.*, 2020; Soroka *et al.*, 2021). Serological methods, although less common due to the lack of viroid-encoded proteins, can detect viroid-specific RNA-protein complexes using antibodies, offering another layer of diagnostic capability (Flores *et al.*, 2014; Sánchez-Navarro *et al.*, 2019).

2.6 Geographical Distribution

Viroids are globally distributed, affecting diverse agricultural regions (Jones & Naidu, 2019; Fujiet *et al.*, 2022). *Potato spindle tuber viroid* (PSTVd) is found in Europe, Asia, and the Americas, impacting solanaceous crops (Flores *et al.*, 2014; Matsushita *et al.*, 2021). *Citrus exocortis viroid* (CEVd) is widespread in citrus-growing regions worldwide (Owens *et al.*, 2012; Reanwarakorn and Dollet, 2016; Imane *et al.*, 2020; Mathioudakis *et al.*, 2023). *Coconut cadang-cadang viroid* (CCCVd) is notably present in Southeast Asia, particularly in the Philippines and Malaysia (Randles *et al.*, 2024; Vadamalai *et al.*, 2024). This extensive distribution highlights the global threat viroids pose to agriculture.

Nigeria produces most of the crops being infected by the different viroids mentioned above, with sometimes observable symptoms seen. However, no effort is geared towards identifying the causal agents, probably due to low expertise in viroid studies, lack of state-of-the-art equipment and other finishing services that require huge amount of funds, among other reasons.

2.7 Management of Plant Viroid Diseases

Managing plant viroid diseases involves stringent phytosanitary measures, such as using certified pathogen-free planting material and implementing rigorous sanitation protocols to prevent mechanical transmission (Flores *et al.*, 2014; Chalam *et al.*, 2020; Kuma *et al.*, 2021). Regular monitoring and early detection using molecular techniques like RT-PCR are essential (Hadidi *et al.*, 2013). Removing and destroying infected plants can help limit viroid spread. Genetic resistance, though limited, is being explored in breeding programmes. Additionally, regulatory measures and quarantine practices are crucial to prevent the introduction and spread of viroids in new regions (Reanwarakorn and Dollet, 2016; Bozbuga *et al.*, 2022; Hammond, 2024).

3.0 CONCLUSION

Viroids, non-coding RNA pathogens, pose a significant threat to global agriculture, causing stunted growth, chlorosis, and fruit deformities in crops like potatoes, tomatoes, citrus, and avocados. They spread through mechanical damage, vegetative propagation, seed transmission, and insect vectors. The economic impact of viroids is profound, affecting both crop production and the ornamental plant industry. Effective management relies on stringent phytosanitary measures, molecular detection techniques, and regulatory controls to prevent their introduction and spread. Despite the extensive research on viroids, gaps remain, particularly in regions like Nigeria where data on viroid presence is lacking. Addressing these gaps amid climate change is crucial for developing comprehensive management strategies and safeguarding agricultural productivity. Enhanced monitoring, early detection, and international collaboration are essential to mitigate the threat posed by viroids.

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