Pest and Disease Management in Ginger Plants: Artificial Intelligence of Things (AIoT)

Olakunle Elijah, *Member, IEEE*, Abiodun Emmanuel Abioye, and Tawanda E. Maguvu

***Abstract*—Ginger (*Zingiber officinale*), a globally cultivated spice crop, is vital to numerous economies. However, its production faces significant challenges due to pests and diseases, which can lead to substantial yield losses. Traditional methods for detecting these threats often rely on visual inspection by human experts, a process that is time-consuming, labor-intensive, and prone to errors. This article examines the potential of artificial intelligence (AI) to address these limitations and transform ginger cultivation. It provides a comprehensive analysis of conventional pest and disease management strategies, identifying their short comings and exploring the potential of emerging AI technologies, including the AI of things' applications, for accurate, efficient, and timely detection and control. By pinpointing the challenges and outlining promising avenues for future research, this study aims to equip agriculturists and researchers with the knowledge necessary to optimize ginger production, enhance food security, and foster sustainable farming practices.**

***Index Terms*—Artificial intelligence (AI), artificial intelligence of things (AIoT), disease detection, ginger, Internet of Things (IoT), machine learning (ML), precision agriculture, sustainable agriculture.**

I. Introduction

GINGER, a perennial herbaceous plant belonging to the *Zingiberaceae* family, is cultivated globally for its versatile rhizomes, used in culinary, medicinal, and aromatic applications [1], [2]. The leading producers of ginger include India, China, Indonesia, Nigeria, Thailand, Jamaica, Bangladesh, Nepal, Cameron, and Japan [3], [4]. Despite its economic significance, ginger production faces numerous challenges, with diseases posing a substantial threat to yield and quality. These diseases, caused by fungi, bacteria, viruses, and nematodes, can significantly reduce yield and quality.

In August 2023, a devastating fungal epidemic ravaged ginger crops in Kaduna State, Nigeria, wiping out approximately 95% of the region's production. The disease, characterized by sudden yellowing and drying of leaves, ultimately led to the rotting of ginger rhizomes in the soil [5]. An assessment conducted by the Institute of Agricultural Research, Ahmadu Bello University, Zaria, identified the disease as a fungal infection, which is both air and soilborne. Similar disease outbreaks have been reported in other ginger-producing countries, including bacterial wilt in Kochi Prefecture, Japan [6], Ethiopia [7], Queensland, Australia [8], and China [8]. Early detection and prediction could have prevented this immense economic loss. These incidents highlight the global nature of ginger diseases and underscore the urgent need for effective disease management strategies to protect ginger crops worldwide. Unfortunately, traditional human-based methods for visually monitoring ginger plants can be inefficient due to factors, such as weather conditions, workload, fatigue, and human error [9], [10]. Furthermore, the use of human experts can be costly for small farmers, time-consuming, and a very tedious task [10]. Hence, the use of artificial intelligence (AI), the Internet of Things (IoT), and the use of artificial intelligence of things (AIoT) tools for plant disease detection have become an active research area.

The use of AI for disease detection, classification, and diagnosis in plants has been largely studied in the literature [11], [12], [13], [14], [15], [16], [17], [18], [19]. Some of the examples of plants in which AI has been applied for disease detection include cassava [18], groundnut (peanut) [20], apple, cherry, corn, grape, orange, peach, strawberry, tomato [19], chili [21], watermelon [22], maize [23], tomato and potato plants [24], cotton plants [25], citrus plant [26], wheat [27], banana [28], almond [29], and ginger [9], [30]. By harnessing the power of AI, IoT, and AIoT, farmers and agricultural scientists can proactively identify and address potential disease outbreaks, ultimately improving crop yields and securing food supplies. Existing literature has provided insight into the diseases affecting ginger detection of diseases and pests in ginger, and prevention techniques [31], [32], [33], [34]. However, there is still a need for a comprehensive review of works on diseases, management, and the use of the latest technologies, such as IoT, AI, and AIoT for disease detection in ginger plants.

The article aims to provide an overview of the techniques and state-of-the-art technologies employed in detecting pests and plant diseases in ginger plants. Accordingly, the contributions of this article are as follows.

1) An overview of the basic pests and diseases that affect ginger plants, symptoms, and causes is discussed.

Received 3 August 2024; revised 10 October 2024 and 3 November 2024; accepted 3 November 2024. Date of publication 21 November 2024; date of current version 11 April 2025. This work was supported by National Information Technology Development Agency (NITDA) under Nigeria Artificial Intelligence Research Scheme (NAIRS/01/24). This grant was managed by Lagos Business School. *(Corresponding author: Olakunle Elijah.)*

Olakunle Elijah is with the Department of Information Technology, School of Computing, Maryam Abacha American University of Nigeria, Kano State P.M.B 3424, Nigeria (e-mail: elij_olak@yahoo.com).

Abiodun Emmanuel Abioye is with the Department of Viticulture and Enology, Fresno State University, Fresno, CA 93740 USA (e-mail: abiodun@mail.fresnostate.edu).

Tawanda E. Maguvu is with the Department of Plant Pathology, University of California, Davis, CA 95616 USA, and also with the Kearney Agricultural Research and Extension Center, Parlier, CA 93648 USA (e-mail: temaguvu@gmail.com).

Digital Object Identifier 10.1109/TAFE.2024.3492323