2) An overview of ginger disease management has been discussed. This includes the conventional method and advanced techniques.
3) An overview of the technology involved in AIoT for prediction and forecast of ginger disease outbreak.

The rest of this article is organized as follows. Section II reviews related literature on the use of AI for ginger disease detection and management. Section III provides an overview of the common pests and diseases affecting ginger plants. Section IV presents the various methods of pest disease management under two categories: conventional methods and smart and precision methods. In Section V, the molecular methods and image processing techniques for pests and disease detection of ginger plants are presented. The use of AIoT for pests and disease management is discussed in Section VI. Section VII discusses the challenges in the adoption of AIoT and Section VIII points out the future directions. Finally, Section IX concludes this article.

## II. RELATED WORKS

Review of plant disease and classification techniques have been presented in [10], [11], [17], [35], [36], and [37]. The authors in [17] and [35] provided a review of various deep learning (DL) architectures and machine learning (ML) techniques for disease classification and detection in various plants. However, the review provided a limited discussion on disease detection and classification in ginger plants. The different imaging techniques for plant diseases were presented in [10]. While the different techniques for early detection and classification of different kinds of disease were discussed, it did not include the ginger plant. Ngugi et al. [37] provided a review of image processing techniques based on visible images for pest and disease recognition in infected plants. The image processing techniques were discussed under three categories: handcrafted, DL, and a hybrid combination of handcrafted and DL techniques. The handcrafted involves basic processes, such as image capture, preprocessing, segmentation, feature extraction, and classification using ML techniques. The DL technique involves the use of DL architectures, such as AlexNet, GoogLeNet, visual graphics group-16 (VGG-16), and several others, while the hybrid involves the combination of handcrafted feature extraction and DL techniques. A review of imaging techniques for several plants was presented but did not include the ginger plant. On the other hand, Yadav et al. [36] focused on ginger but the review was limited to soft rot (rhizome rot) disease and the use of various techniques, such as chemical, biological, and nanotechnology to manage the disease in ginger. The review did consider AI or IoT for the detection and classification of diseases in ginger plants. Similarly, the authors in [31], [32], [33], and [34] have provided a review of diseases related to the ginger plant. For instance, Meenu et al. [32], [33] highlighted the symptoms, causative agents, epidemiology, and protection from these diseases affecting ginger plants as well as disease management. While these works have identified the various diseases affecting the ginger plant, 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.

## III. COMMON PESTS AND GINGER DISEASES

The diseases that affect ginger plants can be classified into biotic and abiotic diseases [32]. Biotic diseases are caused by living organisms, such as fungi, bacteria, viruses, nematodes, and pests. Abiotic diseases are caused by nonliving factors, such as nutrient deficiencies, environmental stresses, such as temperature extremes, and chemical toxicity. This section focuses on the biotic diseases and pests that can affect the quality and quantity of the produced gingers.

### A. Fungal Diseases

Some of the fungal diseases that have been identified in the literature include soft rot or rhizome rot, yellows, wet rot, leaf spot, and storage rots [33].

1) *Rhizome Rot:* Rhizome rot also known as soft rot is a serious disease affecting ginger production and can affect the plant at any developmental stage [36]. The disease is predisposed to water-logged conditions and is caused by several species of *Pythium* [38]. Soft rot initially manifests as wet, brown blisters above the ground sections at the rhizome-stem junction, better known as collars. The blisters/lesions gradually grow larger and coalesce resulting in rot and collapsing of the collar regions. Foliar symptoms appear as yellowing of the tips of lower leaves, which gradually spreads to the leaf blades [36]. The yellowing can progress to all the leaves moving in an upward direction eventually resulting in drooping and withering of the pseudostem. The leaf symptoms could be easily confused with those of withering from *R. solanacearum* or *Fusarium* yellows [36]. However, experienced scouts could easily distinguish this.
2) *Fusarium Yellows:* Fusarium yellows of ginger, caused by *Fusarium oxysporum* f. spp. *zingiberi (Foz)*, is a devastating disease that has significantly reduced the quality and crop yield of ginger worldwide [39]. Infected plants exhibit leaf yellowing, wilting, and a rotten rhizome. Infected plant also produces shriveled tubers and sometimes brown ground tissue. Some of the symptoms appear to overlap with soft rot; however, experienced pathologists can distinguish this by symptom visualization.
3) *Leaf Spot:* The leaf spot diseases caused by *Phyllosticta zingiberi* can be aggressive and destroy the chlorophyllous tissues causing a significant reduction in yield. The incidence of the disease is higher, and the yield of the rhizome is reduced when the ginger is cultivated continuously without the rotation of the crop [33], [40]. Symptoms include round, oval to elongated spots on the leaves, which are white at the center, thin and papery, and more often torn up. Sometimes pycnidia (black) can be observed at the center of the spots. As the disease progress, infected areas dry and fall out resulting in shotholes. Fig. 1(c) shows infected ginger leaf spot disease.
4) *Ginger Rust (Puccinia zingiberis):* Ginger rust, caused by the fungus *Puccinia zingiberis*, manifests as yellow–orange rust pustules on leaves, reducing photosynthetic activity and weakening the plant. Severe infections can lead to defoliation and reduced rhizome yield.