

TABLE I
SUMMARY OF GINGER DISEASES AND PESTS [48]

| Diseases | Causes | Favorable Conditions | Symptoms | Outcome |
|---------------------|---|--|--|---|
| Fungal Diseases | | | | |
| Rhizome rots | <i>Pythium</i> spp., <i>Fusarium</i> spp., and <i>Rosellinia</i> spp. | High soil moisture, high temperatures above 30 °C, poor drainage, and nematode infestation | Degeneration of rhizomes into a black, putrefying mass leaf tips, sheaths, margins, and gradually whole leaves turn yellow | Desiccation and death of ginger plant |
| Fusarium Yellows | <i>Fusarium oxysporum</i> f. sp. <i>zingiberi</i> | Warm and humid, poor drainage | Leaf yellowing, wilting, and a rotten rhizome | Degeneration of plant health and reduced yield |
| Leaf spots | <i>Phyllosticta</i> spp., <i>Colletotrichum</i> spp., <i>Helminthosporium</i> spp., <i>Cercospora</i> spp. and <i>Septoria</i> spp. | Overhead watering, poor air circulation, and high humidity | Small, circular, brown to dark brown spots with yellow halos on the leaves. Spots may merge to form larger lesions. | Degeneration of plant health and reduced yield |
| Storage rot | <i>Pythium</i> spp., <i>Fusarium</i> spp., <i>Aspergillus</i> spp., and <i>Penicillium</i> spp. | High soil moisture, high temperatures above 30 °C, poor drainage, and nematode infestation | Colored, watery, mushy, and foul-smelling rhizomes | Reduced shelf life of stored rhizomes |
| Bacterial Diseases | | | | |
| Bacterial wilt | <i>Ralstonia solanacearum</i> | High soil moisture, poor drainage and nematode infestation | Progressive yellowing and wilting from the lower leaves to the whole plant | Milky exudate of the rhizomes when cut |
| Storage rot | <i>Ralstonia solanacearum</i> , <i>Erwinia</i> spp. | High temperatures above 30 °C, poor drainage, and nematode infestation | Colored, watery, mushy, and foul-smelling rhizomes | Reduced shelf life of stored rhizomes |
| Nematode Diseases | | | | |
| Root-knot nematodes | <i>Meloidogyne</i> spp. | Warm and moist soil, sandy soils | Stunting, chlorosis, poor tillering ,and necrosis of leaves | Rotting rhizomes and water soaked areas |
| Viral Diseases | | | | |
| Ginger mosaic | Cucumber mosaic virus (CMV) | High humidity, warm temperatures | Yellowish and dark-green mosaic on leaves, and stunted leaves and rhizomes at the late stage of infection | Severe reduction of rhizome yield |
| Chlorotic fleck | Chlorotic fleck virus (CFV) | High humidity | Light green to bright yellow interveinal chlorotic flecks | Stunted growth and yield reduction |
| Ginger Pest | | | | |
| Shoot borer | <i>Conogethes punctiferalis</i> | 30–33 °C and relative humidity range 60%-90%, active from July to October | Yellowing and drying of leaves and bore hole of infested pseudo stems. | Damaged ginger plants. |
| Rhizome scale | <i>Aspidiella hartii</i> | Dry weather | Shriveled and desiccated rhizomes affecting. | Rhizomes dries and cannot germinate |
| Leaf roller | <i>Ancistroides folus</i> larvae, and larvae of several other moths, | Temperature 26–35 °C, relative humidity 41%-100 % | Leaves become folded or rolled longitudinally. | Complete defoliation of ginger plants |
| Rhizome fly | <i>Calobata</i> spp. | Warm and humid weather | Yellowing of plants and rotting of rhizomes. | Drying of aerial plants and rotting of rhizomes |
| White grub | <i>Phyllophaga</i> spp. | Warm and humid weather. | Yellowing and wilting of shoots. | Large holes in rhizomes and reduce market value of produce. |
| Thrips | Family <i>Thripidae</i> | Warm and humid weather. | Leaves roll up. | Young leaves and shoot wilt and dry out. |

IV. DISEASE MANAGEMENT

Ginger disease management has been discussed in the literature [49], [50], [51], [52], [53], [54], [55], [56], [57]. Ginger disease management can be classified into the conventional methods and smart precision methods.

A. Conventional Methods

Conventional methods of disease management in ginger involve practices that have been traditionally used and rely primarily on established agricultural techniques, chemical applications, and biological controls.

- 1) *Cultural Practices*: Cultural practices involve the use of crop rotation [58], [59], [60], sanitation [61], intercropping [62], [63], and soil management [64] methods. In crop rotation, ginger cultivation is done by rotating with nonhost crops that are not susceptible to ginger-specific diseases. For instance, a cycle of 2–4 years of rotation of ginger crops and other crops, such as paddy, potato,

and mustard, was reported in [59]. This helps in reducing pathogen load in the soil, thereby disrupting the life cycle of soilborne pathogens. This requires good management from the farmers. Aside from crop rotation, intercropping, which is the practice of growing two or more crops in proximity, offers several benefits to ginger cultivation [62], [63]. This is due to some factors, such as improvement of soil structure, reduction in the spread of soilborne diseases, and reduction in light intensity [65]. The use of sanitation involves maintaining a high level of hygiene to prevent the spread of diseases [61]. The infected plants are destroyed, while tools and equipment are properly cleaned to avoid cross contamination. In the soil management method, good drainage systems are put in place to avoid water logging [64]. This helps prevent root and rhizome rot. Effective irrigation method, such as drip or furrow irrigation, which delivers water directly to the root zone, helps reduce the spread of fungal diseases. While these cultural practices have proved to be successful, ginger