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# Ginger Bacterial Wilt (Ralstonia solanacearum) Management Approach in Ethiopia: A Review

Afework Legesse
Department of Horticulture, Jimma Agriculture Research center, Jimma, Ethiopia

**Abstract**
Ginger is produced for its spice and medicinal properties in tropical and subtropical climates around the world. In diverse parts of the world, ginger, like most cultivated crops, is affected by biotic and abiotic variables. One of the most frequent diseases in many crops, including ginger, is bacterial wilt (Ralstonia solanacearum). This review aims to highlight key scientific findings on this economically significant ginger wilt disease in Ethiopia, as well as disease management choices, problems and future considerations. Cultural, chemical use, Biological, and Resistant Cultivars are some of the primary management approaches that can aid in the reduction of ginger bacterial wilt disease effects. However, due to the disease's novel strain creation, no one effective management plan exists. As a result, using an integrated disease management approach is the most effective, ecologically friendly, and cost-efficient option for consumers. Because there is currently no single effective control measure against the target pathogen, a well-coordinated effort is needed to design an integrated disease management program that will help to reduce disease related damage and yield loss.
**Keywords:** Bacteria wilt, Ginger, Integrated management, Race
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## 1. Introduction

Ginger (Zingiber officinale Rosc.) is a popular spice crop grown for its aromatic rhizomes, which are used as both a spice and a medicinal (Sharma *et al.* 2010). It is typically consumed as a fresh paste, dried powder, slices preserved in syrup, candy, as a beverage or as flavouring agent. It has also some traditional medicine value for the treatment of flu and stomach ache (Girma and Digafie 2004). Ginger rhizome contains volatile oil, fixed oil, pungent compounds, resins, starch, protein, and minerals. Ginger has been commonly farmed as a cash crop in the South, Southwest, and Northwestern portions of the country since its arrival in the thirteenth century. Diseases are one of the most significant limits to ginger production, and among these, bacterial wilt is one of the most important problems with ginger worldwide, and particularly in Ethiopia (Mansfield *et al.*, 2012; Merga *et al*., 2018). Bacterial wilt (Ralstonia solanacearum (Smith) Yabuuchi is very important in major ginger producing areas of Ethiopia, where ginger is widely and mainly produced for commercial purposes (Habetewold et al. 2015). Ralstonia solanacearum, has a wide host range (Yabuuchi et al. 1995). Bacterial wilt has been observed on potato, tomato, pepper, enset, banana, and ornamentals in Ethiopia, but it has just lately been reported on ginger (Bekele et al. 2016). Disease incidence in the field usually ranges from 10 to 40%, but the disease is also known to destroy the crop completely (Zhang *et al.,* 2001). Bacterial wilt disease of edible ginger causes severe economic damage in many countries, including China, India, Indonesia, Japan, Malaysia, Mauritius, the Philippines, and the United States (Hawaii) (Kumar and Sharma, 2004) and the loss in yield due to the disease in ginger is 100 per cent in Ethiopia (Habetewold *et al.,* 2015). Tariku *et al* (2016) also reported that, a severe outbreak of ginger wilt disease identified as bacterial wilt caused by *R. solanacearum* with disease incidence of 80-100% in Ethiopia. The epidemics of this disease caused up to 100% losses of ginger yield and continued until today. This has resulted in a drastic decline of ginger production in Ethiopia from its peak of 7345 tone in 2010 with export value of $22323000 to a volume of 3648 tone and value of $7893000 in 2015/16 (MoA, 2016).

## 2. Economic importance of Ginger bacterial wilt disease

Ginger bacterial wilt (Ralstonia solanacearum) is a very destructive disease and has been reported from most areas of Ethiopia where Ginger is grown commercially (Habetewold *et al.,* 2015; Merga *et al*., 2018). The host range of *R. solanacearum* is unusually wide for a plant pathogen, affecting over 450 host species in 54 botanical families (Wicker *et al*., 2007). More than 55 crops and wild species are affected by R. *solanacearum* crops such as potato, tobacco, tomato, egg plant, banana, chili, bell pepper, ginger and peanut are highly susceptible to the disease (Hayward, 1991).

Table 1. Mean incidence, severity and prevalence of ginger wilt at Boloso-Bombe and Hadaro-Tunte district.

| Year of production | GWD intensity at Boloso-bombe district | | | GWD intensity at Hadaro-Tunte district | | |
|---|---|---|---|---|---|---|
| | Prevalence (%) | Incidence (%) | Severity (%) | Prevalence (%) | Incidence (%) | Severity (%) |
| 2015 | 100 | 100 | 78 | 100 | 100 | 78 |
| 2016 | 100 | 65 | 60 | 100 | 65 | 60 |
| 2017 | 100 | 95.5 | 28.2 | 100 | 95.5 | 28.2 |

Source: Seid *et al.*, 2020

According to Seid *et al.*, (2020), the average ginger wilt disease (GWD) incidence was 100% and the severity was 85% in Boloso-bombe and Hadaro-tunte districts (table 1). Habtewolde *et al.* (2015) also reported in their survey result, SNNPRS (Dawro, Wolayta, Kenbata tenbaro, Hadiya, Gomogofa, Konta, Alaba, Sheka, and Bench maji) and Gambella region (Majang) zone ginger were found devastated by the bacterial wilt and cause yield loss up to 98.9% (Fig1). This is due to the prevailing ideal weather condition for the bacteria epidemics (average rain fall, 287.9 mm, Temperature max, $27.8^{O}C$ & Temperature min. $17.1^{O}C$) and using of latently infected seed rhizome..

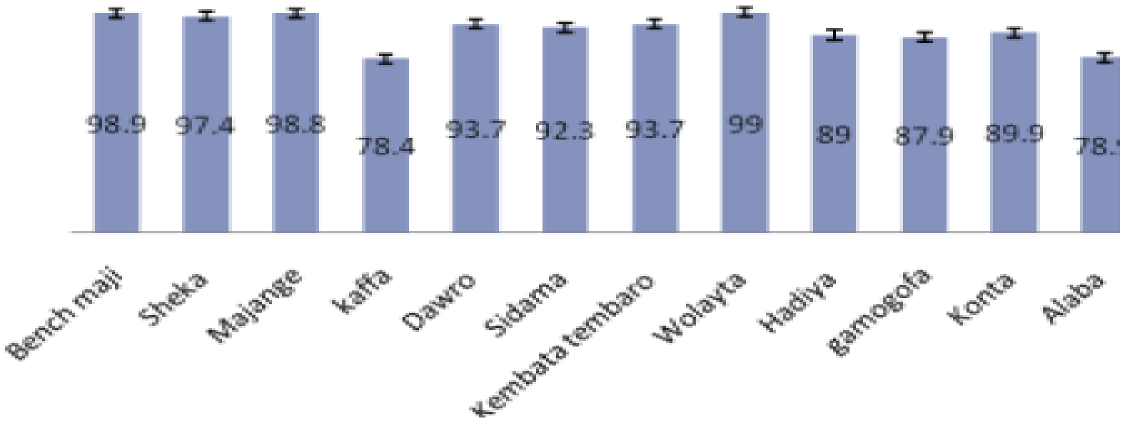


Figure 1. Incidence of ginger bacterial wilt in different parts of Ethiopia
Source: Habtewolde *et al.,* 2015

## 3. Pathogen

Ralstonia solanacearum is a bacterium species with a wide range of characteristics. It's a rod-shaped bacterium that's strictly aerobic, gram negative, non-spore producing, non capsulated, and nitrate-reducing (Stevenson *et al.*, 2001). The bacterium is incapable of hydrolyzing starch or degrading gelatin. It is also susceptible to desiccation and is inhibited by low sodium chloride concentrations in broth culture. Except for specific Race 3 strains harmful to potatoes that can develop at lower temperatures, optimum growth is between 28 and 32 degrees Celsius" (Stevenson *et al.*, 2001).

The *Ralstonia* species can be similar in phylogeny and chemotaxonomic properties, and different in pathogenicity, host relationship and other phenotypic properties (Denny and Hayward, 2001).

A phylogenetically meaningful classification scheme was developed based on DNA sequence analysis. This scheme divides the complex species into four phylotypes that broadly reflect the ancestral relationships and geographical origins of the strains. Accordingly, phylotype I, II, III and IV strains are originated from Asia, America, Africa, and Indonesia, respectively. The phylotypes are further subdivided into sequevars based on the sequence of the endoglucanase (*egl*) gene (Fegan and Prior, 2005).

## 4. Mode of infection

R. *solanacearum* is a soil-borne pathogen that naturally infects roots. The root inhibiting bacteria R. solanacearum penetrates through wounds caused by transplanting, cultivation, insects, or some nematodes, as well as natural wounds where secondary roots grow (McCarter, 1991). The bacterium has a preference for the vascular system once inside the host, where it grows rapidly, filling the xylem with bacterial cells and slime. After the infection has taken hold, it spreads up the vascular system, the xylem, and eventually limits water transportation, causing wilting (Tahat and Sijam, 2010). Highly phytopathogenic, the bacterial cells penetrate the xylem vessels and spread throughout the plant establishing foci of infection (Timms-Wilson *et al.*, 2001); virulence factors that the bacteria use in host colonization are the lytic enzymes, the extra cellular polysaccharides, endoglucanases and endopolygalacturonases are critical factors in colonization and cause the rot and disintegration of the tissue (Timms-Wilson *et al.*, 2001). It is known according to Saile *et al.*, (1997) and confirmed by Timms-Wilson *et al.*, (2001) that extracellular polysaccharide production contributes to the biomass of colonizing bacteria, causing a rapid wilting of infected plants.

## 5. Disease Symptoms and Signs

The symptoms caused by R. solanacearum pathogen on ginger include the following:

a) "Green wilt," the diagnostic symptom of the disease. This occurs early in the disease cycle and precedes leaf yellowing. Infected green ginger leaves roll and curl due to water stress caused by bacteria blocking the water-conducting vascular system of the ginger stems.
b) **Leaf yellowing and necrosis.** Leaves of infected plants invariably turn yellow and then brown. The yellowing should not be confused with another disease of ginger causing similar symptoms, Fusarium yellows. Note: Plants infected by the fungus, *Fusarium oxysporum* f. sp. *zingiberi*, do not wilt rapidly, as in bacterial wilt. Instead, infected ginger plants are stunted and yellowed. The lower leaves dry out over an extended period of time. Under conditions favorable for disease development, the entire shoot becomes flaccid and wilts with little or no visible yellowing. However, the plant dries very rapidly and the foliage becomes yellow-brown in 3 to 4 days (Fig. 2).
c) **Plant stunting.** Diseased plants grow poorly and may be stunted.
d) **Plant decline and death.** Young succulent shoots frequently become soft and completely rotted and these diseased shoots break off easily from the underground rhizome at the soil line. Diseased plants can decline rapidly and die before harvest.
e) **Rotten rhizomes** often discolored. The underground parts are also completely infected. Grayish-brown discoloration of the rhizomes may be localized if the disease is at an early stage of infection, or discoloration may be general if the disease is in an advanced stage.
f) **Water-soaked appearance of infected rhizomes and stem vasculature.** A better diagnostic feature is the extensive bacterial ooze that shows as slimy, creamy exudates on the surface of a cut made in the rhizome or on the above-ground stem of an infected plant.
g) **Discoloration of vascular tissues**

Signs can be useful in diagnosing the Pathogen and the disease. These are signs of bacterial wilt of ginger:

i. **Bacterial streaming**, i.e., large populations of bacteria that exude from the cut surface of infected plant tissue when observed with a microscope or observed macroscopically when a diseased ginger rhizome is suspended in a glass or beaker of water (Fig.3).
ii. **Bacterial ooze from infected tissues, especially from infected rhizomes.** Ooze is the emission of bacterial colonies from infected tissues, seen as moist, milky mounds collecting on the tissues' surfaces (Fig.3).

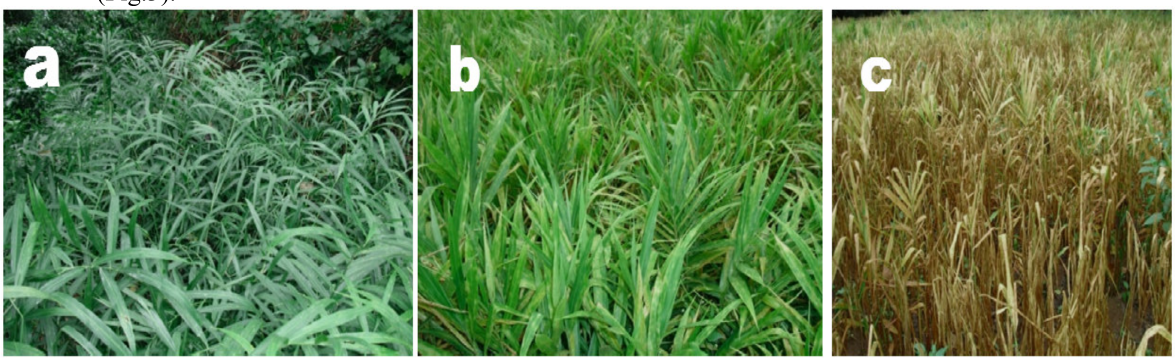


**Figure 2. Ginger bacterial wilt showing progressive disease symptoms, normal (a), wilting and yellowing (b) and complete death of the plant (c).**

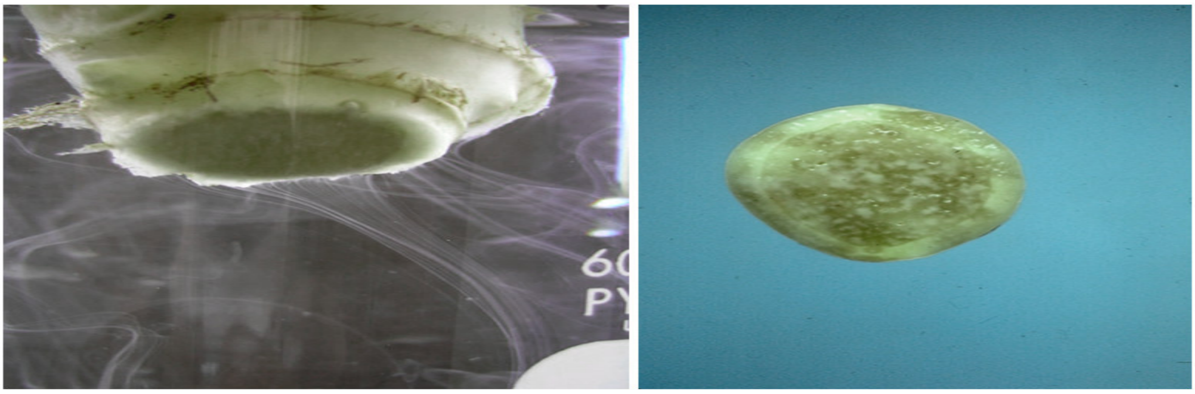

**Figure 3. Signs of bacterial wilt of edible ginger**

**Left:** Bacterial streaming from an infected ginger rhizome suspended in water. The streaming begins only a few minutes after placing the cut rhizome in water. This is a reliable assay for bacterial wilt. **Right:** Milky, bacterial ooze forming the cut surface of a discolored, infected ginger rhizome. The bacterial colonies may take one or two days to form, and form more rapidly in a humid environment. One may use either of these two signs of the pathogen to diagnose bacterial wilt of ginger caused by *Ralstonia solanacearum*.

## 6. Sustainable Bacterial Wilt Management Approaches

It's difficult to control bacterial wilt of plants once R. solanacearum has established itself in the soil. This is due to the vast host range, lengthy survival in the soil, transmission in a variety of ways (including planting materials, irrigation water, agricultural implements, and vectors), latent infection in vegetation, and genetically varied strains (APS, 2005). However, knowing these features of the disease is quite useful to analyze conditions that determine disease development and plan sound disease management strategy. Up to now there is no single control effective measure against the pathogen (Merga *et al.*, 2018; Lemessa and Zeller, 2007). However, a combination of several approaches has been able to reduce bacterial wilt to some extent. Host resistance, agronomic practices, cultural practices, biological control, chemical control, and integrated disease management are some of these methods (IDM).

### 6.1 Host Resistance

Exploitation of host resistance for management of bacterial wilt can be one of the important eco-friendly disease control strategies. The stability of resistant varieties is highly affected by pathogen strains, temperature, soil moisture and presence of root-knot nematodes, host pathogen interaction, breeding methodology, and genetic linkage between resistance (Boshou, 2005). Therefore, increasing varietal resistance in the framework of an integrated approach may be the most suitable approach to control the disease (Denny, 2006). The availability of resistance sources, their diversity, genetic linkage between resistance and other agronomic traits, differentiation and variability in pathogenic strains, the mechanism of plant pathogen interactions, and breeding or selection methods have all been influenced host breeding for resistance. However, in Ethiopia low genetic diversity and /or narrow genetic base of ginger genotypes is bottle neck to develop bacterial wilt resistance variety.

### 6.2 Biological Control

Use of biological controls products for soil borne pathogen has gained popularity in recent years due to environmental concerns raised on the use of chemical products in disease control (Haas and De'fago, 2005). A number of mechanisms are involved in controlling and suppression of the pathogen by mycorrhizal fungi roots among them exclusion of pathogen, changed nutrition, lignifications of cell wall, and exudation of low molecular weight compounds (Tahat *et al.*, 2011). Successful trials using biological control agents in the field are introduced in Table 2.

Table 2. Various biocontrol agents that have been tested in the field to control bacterial wilt diseases caused by *Ralstonia solanacearum* (2005–2014)

| **Microorganisms** | **Mechanisms** | **BE (%)** | **Yield*** | **Ref** |
|---|---|---|---|---|
| Bacillus subtilis strain 1JN2, Myroides odoratimimus 3YW8, Bacillus amyloliquefaciens 5YN8, and Stenotrophomonas maltophilia 2JW6 strains | Unkown | >50% in Ginger | **NA** | W.Yang *et al.*, 2012 |
| *Ralstonia pickettii* QL-A6 | Competition | 73% in the tomato | NA | Wei *et al.,* 2013 |
| *Bacillus amyloliquefaciens* + bio-organic fertilizer (BIO23) *B. subtilis* + bio organic fertilizer (BIO36) | Plant growth promotion | 58–66% in the potato | 64-65% | Ding *et al.*, 2013 |
| *Bacillus* sp. (RCh6) *Pseudomonas mallei* (RBG4) | Production of inhibitory compounds and siderophores | 81% in the eggplant | 60-90% | Ramesh *et al.*, 2012 |
| *B. amyloliquefaciens* QL-5, QL-18 + organic fertilizer | Decreased root colonization by the pathogen | 17–87% in the tomato | NA | Wei *et al.,* 2011 |
| *B. amyloliquefaciens* Bg-C31 | Production of antimicrobial protein | 60–80% in Capsicum | NA | Hu *et al.,* 2010 |
| *Acinetobacter* sp. Xa6, *Enterobacter* sp. Xy3 | Rhizocompetence and root colonization | 57–67% in the tomato | 32-41% | Xue *et al.,* 2009 |
| *B. vallismortis* ExTN-1 | Induction of systemic resistance | 48–49% in the tomato | 17% | Thanh *et al.,* 2009 |

### 6.3 Agronomic practice

#### 6.3.1 Crop Rotation

Rotation with non-host plants is an effective means of decreasing the level of R. solanacearum populations in soil. Crop rotation with non-susceptible crops reduces soil borne populations of the bacterium (Katafire *et al.*, 2005;Janiver *et al.*, 2007). Appropriate rotation period and non-host break crops should be identified and used. Shifting planting dates to cooler periods of the year can help escape the disease. While continuous cropping with the same susceptible host plant may end up in the establishment of specific plant pathogenic populations, thus crop rotation breaks this detrimental effect and result in the reduction plant diseases caused by soil borne pathogens (Janiver *et al*., 2007). In line with this Katafire *et al*. (2005) found that rotating potato cultivation with wheat, sweet potato, maize, millet, carrots, sorghum, or phaseolus beans reduced the incidence of wilt by 64 to 94% while the yield of potato was 1 to 3 fold higher than that of mono-cultured potato. Similarly, the onset of bacterial wilt was delayed by 1 or 3 weeks and wilt severity was reduced by 20–26% when a susceptible tomato variety was grown after corn, lady's fingers, cowpea, or resistant tomato (Adhikari *et al*., 1998).

#### 6.3.2 Soil amendment

Previous studies revealed that the application of fertilizers reduced the incidence of bacterial wilt. Calcium (Ca) is the most well-known fertilizer to suppress disease. Increased Calcium concentrations in plants reduced the severity of bacterial wilt as well as the population of *R. solanacearum* in the stems of the tomato (Yamazaki *et al.*, 2000). Furthermore, an increase in Ca uptake by tomato shoots correlated with lower levels of disease severity (Yamazaki *et al.*, 2000). Lemaga *et al.* (2001) reported that the application of nitrogen (N) + phosphorus (P) + K and N + P (application rate of each fertilizer = 100 kg $ha^{-1}$) reduced bacterial wilt by 29% and 50%, respectively, and increased the yield of potatoes to 18.8 t $ha^{-1}$ and 16.6 t $ha^{-1}$, respectively, which was higher than that in untreated controls (11.2 t $ha^{-1}$). Hacisalihoglu *et al.* (2007) reported that bacterial wilt induced changes in the distribution of nutrients, especially Ca, B, and P in tomato leaves. Li and Li and Dong (2013) showed that the combined amendment of rock dust and commercial organic fertilizer reduced the incidence of bacterial wilt in the tomato. A single amendment with rock dust also effectively reduced the incidence of bacterial wilt in the tomato and higher soil pH and Ca content were key factors in the control of bacterial wilt by the rock dust amendment.

### 6.4 Physical methods

#### 6.4.1 Soil treatment

To eliminate ginger wilt disease caused by R. solanacearum, effective treatments for ginger rhizomes used as seed should also be considered (TEAP, 2012). L. Mao reported that Dazomet (DZ) is a potential alternative to methyl bromide (MB) for combating ginger bacterial wilt caused by Ralstonia solanacearum. In field trials, both

DZ 50 PE and DZ 80 PE treatments resulted in a sharp reduction in colony-forming units of R. solanacearum on media and high yields (Mao *et al*., 2017). R. solanacearum in ginger is both soil borne and seed borne; however, soil fumigation can solve only the soil-borne problem. Vinh *et al.* (2005) found that soil solarization using transparent plastic mulches for 60 d prior to the planting of tomatoes reduced the incidence of bacterial wilt.

### 6.4.2 Seed treatment

Contaminated planting material is one of the primary inoculum sources for field infection. Disinfection of seed pieces prior to planting is an important approach to the control of bacterial wilt of ginger. The soaking of seeds in a low sodium chloride solution was previously found to increase seedling vigor and tolerance to *R. solanacearum* in the tomato (Nakaune *et al.,* 2012). Soaking of ginger seed in hot water at 50ºC for 10 minutes (Nishina *et al.,* 1992) is the usual pre-plant preparation. Shorter exposure times give insufficient heat penetration, and longer soaking periods result in heat injury to the seed piece and growth of stunted crops (Nishina *et al.,* 1992). Another study reported that rhizome solarization on ginger seeds for 2 to 4 h reduced bacterial wilt by 90–100% 120 d after planting, and that ginger seeds sterilized with discontinuous microwaving (10-s pulses) at 45°C reduced the incidence of wilt by 100% (Kumar and Sood, 2005).

## 6.5 Chemical control

The combination of methyl bromide, 1,3-dichloropropene, or metam sodium with chloropicrin signifcantly reduced bacterial wilt in the field from 72% to 100% and increased the yield of tobacco and the tomato. The yield of the pesticide-treated tomato was 1.7 to 2.5 fold higher than that of the untreated control (Santos *et al*., 2006). Acibenzolar-S-methyl (ASM) has been proposed to induce systemic resistance (Pradhanang *et al*., 2005). The combination of ASM and thymol signifcantly reduced the incidence of disease and increased the yield of the tomato, whereas ASM or thymol alone did not (Hong *et al*., 2011). Silicon (Kurabachew and Wydra, 2014) or Si reduced the incidence of bacterial wilt through induced resistance. Wang *et al.* (2013) reported that Si-mediated resistance was associated with increases in the amount of microorganisms in the soil as well as soil enzyme activity (urease and acid phosphatase). The bactericides Terlai has been tested in Taiwan under both greenhouse and field conditions (Hartman *et al*., 1994) and it was found that chemical control through soil fumigation and antibiotics (Penicillin, Ampicillin, Tetracycline and Streptomycin) has shown suppression of the pathogen.

## 6.6 Integrated Disease Management

Integrated Disease Management (IDM) is a set of approaches for reducing disease damage to bearable levels that includes cultural, host resistance, biological, and chemical applications that are ecologically friendly, economically practicable, and socially acceptable (Agrios, 2005). These integrated approaches reduce or delay disease severity during the critical periods of vegetative and reproductive plant growth. To reduce the impact of bacterial illness on ginger, growers must carefully incorporate recommended techniques such as crop rotation, sanitation, use of treated or healthy seeds, tolerant cultivars, soil solarization, soil biofumigation, in organic soil amendment, and adequate seed treatment. IPM reduced bacterial wilt disease by 20–100% in the field or under laboratory conditions, and typically combines two or three methods among cultural practices and chemical and biological methods (Yuliar *et al*., 2015). Bacterial wilt management necessitates a multidisciplinary strategy, which can only be effective if accompanied by systematic and ongoing community awareness activities. To manage illness and boost yields, it is important to select and combine diverse disease control strategies that are practical, cheap, and environmentally friendly.

## 7. Recommendations and concluding remarks

This review highlights the necessity for an integrated disease management plan to combat the deadly bacterial wilt disease of ginger, particularly in Sub-Saharan African countries such as Ethiopia. Various control tactics have been used to combat the *R. solanacearum* thus far; however, there is no one effective control measure against the infection. By combining a biological control agent with different agronomic practice such as soil amendments (simple organic compounds, compost, or plant residue, fertilizer) and crop rotation, using chemical and seed and soil treatment we will be able to find solutions.

As a result, implementing an integrated disease management strategy is crucial. To control the damage inflicted by the pathogen both at the regional and national level, more effort should be made to improve soil health, availability of clean planting to minimize the transfer of latently infected planting material from region to region by establishing quarantine centers, improve farmers' knowledge of proper production systems, and so on.

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