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REVIEW ARTICLE

Unmasking the hidden threat: a review of damage and losses due to phytopathogenic bacteria

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ABSTRACT

Phytopathogenic bacterial diseases have always been given less attention than other pathogenic diseases leading to their neglect in management. This review aims at synthesizing and generating evidence that although phytopathogenic bacterial diseases cause comparatively less damage and losses, they still cause substantial losses that are too significant to be ignored. A narrative review was conducted using data sources published between 2000 and 2024 utilizing reports, articles, and books using online search and bibliographic methods across three e-bibliographic databases: PubMed, ResearchGate, and Google Scholar. After the review, it was found that Phytopathogenic bacteria cause direct and indirect damage. Direct damage affects host plant cells, causing cell wall and membrane destruction, organelle damage, hormonal disruption, vascular blockage, and cell death. Indirect damage includes plant death, reduced nutrient assimilation, and abnormal growth. These disruptions in plant growth and metabolism reduce crop productivity resulting in yield loss of up to 100%, economic losses of up to $1 billion annually, and diminished quality of agricultural produce which vary depending on the phytopathogen species, crop, and geographical location. Despite initial reports that phytopathogenic bacterial diseases resulted in less damage and yield loss than other pathogens, it is evident that Phytopathogenic bacteria can cause substantial losses that cannot be ignored. Future research should focus on improving management practices, particularly in developing IPM packages, Economic Injury Level (EIL), and advanced technologies such as Machine Learning, the Internet of Things (IoT), and Unmanned Aerial Vehicles (UAV) to effectively mitigate the impact of Phytopathogenic bacteria in crops.

Keywords: damage; losses; management practices; phytopathogenic bacteria

INTRODUCTION

Phytopathogenic bacteria are microscopic prokaryotic cells that can interact with plants with the primary objective of obtaining nutrients and ultimately causing disease to the plant. Phytopathogenic bacteria represent an important group of pathogens causing several important diseases affecting crop productivity. Among the approximately 7100 diverse species of Kingdom Monera, around 200 species belonging to this Kingdom are reported to be the pathogen that can cause disease to the plant (Buttimer et al., 2017). Although this diversity of species of phytopathogenic bacteria belongs to different several genera, only eight phytopathogenic bacteria genera are important in Agricultural production which are; *Pseudomonas, Ralstonia, Agrobacterium, Xanthomonas, Erwinia, Xylella, Pectobacterium,* and *Dickeya* (Mansfield et al., 2012).

As stated earlier, the Phytopathogenic bacteria interact and establish relationships with the host plant to obtain nutrients. Initially, the interaction occurs on the plant surface, such as the phyllosphere and rhizosphere, and as the infection progresses, phytobacteria enter the host vascular tissues and intercellular spaces to continue nutrient uptake (Fatima & Senthil-Kumar, 2015; Prasannath, 2013). Although plants can impose defense mechanisms to prevent the establishment of nutrient relationships, successful infection is facilitated by the secretion and injection of virulence factors. These factors include toxins, enzymes, exopolysaccharides (EPS), phytohormones, and ice-nucleation-active (INA) proteins (Pfeilmeier et al., 2016). The activities of the Phytopathogenic bacteria in the host plants including nutrient uptake and the virulence factors' release have a negative impact by damaging not only the cellular structure and integrity of the host plant but also compromising the metabolic processes and the physiology of the plant. The compromised plant metabolic activities are later revealed through losses by reduced final yield, quality, and financial losses.

While Tampakaki et al. (2009) stated that bacterial diseases cause less damage and losses than other plant viruses such as viruses and fungi, this review aims to synthesize evidence and to justify that though the losses caused by phytopathogenic bacteria are comparatively lower to other pathogens, they still cause substantial losses region-wise and globally significant enough to capture the attention of management practices. By reviewing the damage and losses caused by Phytopathogenic bacteria as reported in different parts of the world, this paper will highlight the importance of addressing these pathogens to avoid their potential losses and damage on crops.

MATERIAL AND METHODS

I conducted a narrative review of data sources on Phytopathogenic bacteria losses and damage to crops to address the study's objectives. Data reported in this review were obtained from reports, articles published in peer-reviewed journals, book chapters, and books. The inclusion criteria focused on sources published in English between 2000 and 2024, providing specific information on crop losses and damages caused by Phytopathogenic bacteria. Sources lacking this focus were excluded. To gather relevant information, I used both online search and bibliographic methods utilizing three e-bibliographic databases: PubMed, ResearchGate, and Google Scholar. The primary search keywords included: Phytopathogenic bacteria losses; Phytopathogenic bacteria damage; Losses due to Bacteria on crops; and Damage due to Bacteria on crops.

FINDINGS OF THE REVIEW

The results of the present narrative review are presented in two major categories, which are damage and losses due to Phytopathogenic bacteria.

Damage

The damage caused by the Phytopathogenic bacteria can be divided into major categories namely; Direct damage and Indirect Damage. Direct damage includes the primary damage of the host cells resulting from the infection by phytopathogenic bacteria while indirect damages are the consequences of the primary or direct damage of Phytopathogenic bacteria to the host plant. Indirect damage can also be referred to as Secondary damage.

Direct Damage on Phytopathogenic Bacteria on Plant Cells

Cell membrane damage

With the primary objective of phytopathogenic bacteria being the acquisition of nutrients from plant tissues (Fatima and Senthil-Kumar, 2015), the multilayered outer cell membrane becomes a barrier, especially for intercellular phytopathogenic bacteria such as *Pseudomonas syringae*. To overcome this barrier and access the nutrients inside the cells, phytopathogenic bacteria consist of pore-forming proteins (PFPs) also known as pore-forming toxins. More than 30% of the Phytopathogenic bacteria are PFPs (Popoff, 2024). The role of PFPs is to form pores on the plasma membrane by their interaction with the specific receptors found on the cell membrane followed by followed by protein oligomerization and structural rearrangements leading to the formation of transmembrane pores thus promoting nutrient leakage from the cells of hosts, disrupting membrane integrity and eventually cell death (Prasannath, 2013) as illustrated in Figure 1. This can be found in *Pseudomonas syringae* pv. Syringae that secrete lepodepsipeptides toxins such as syringomycins and syringopeptins increase the permeability of the membrane of the host thus aiding the bacteria to acquire nutrients from the lysis of the cells (Benali et al., 2014; Ichinose et al., 2013; Prasannath, 2013).

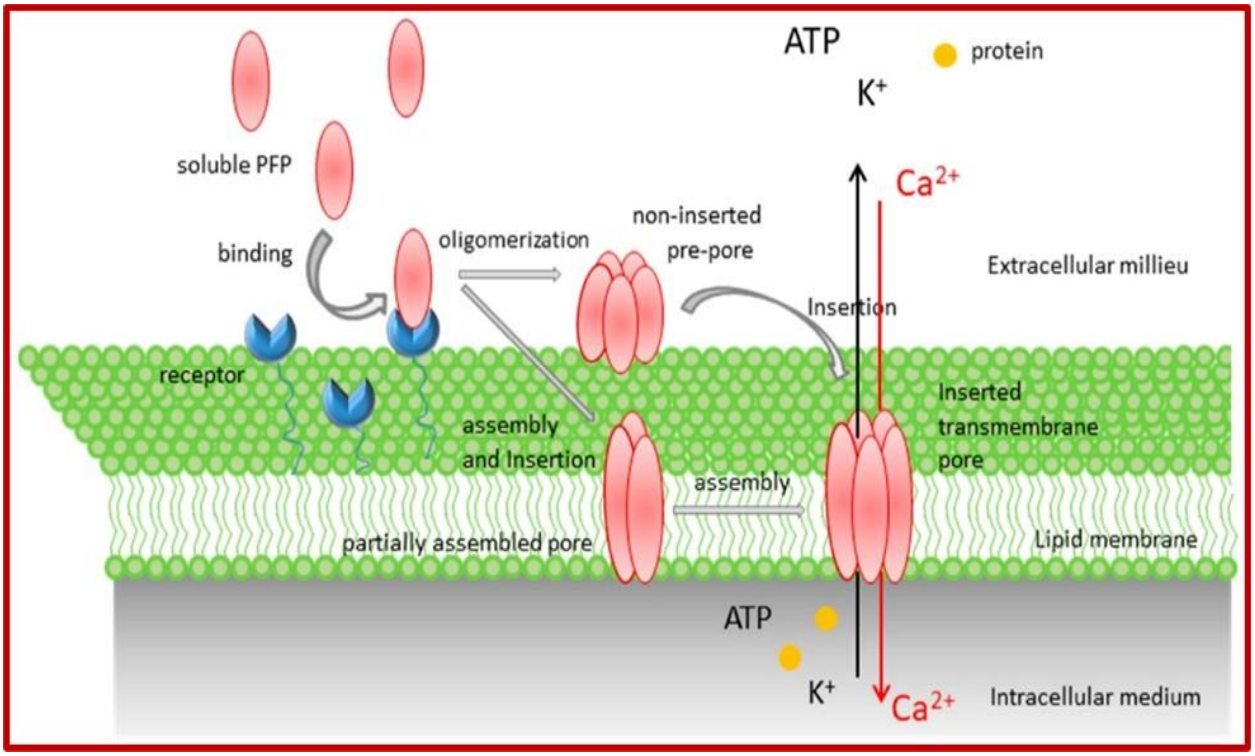

Figure 1. Mechanism of Pore-Forming Proteins (PFPs) on inducing pore formation in the cell membrane of the host. Source: Ostolaza et al. (2019).

Cell death (Necrosis)

Necrosis is the cell death caused by effector proteins from the Phytopathogenic bacteria to the host plant upon infection characterized by sunken lesions on the leaves, stems, or fruits. Necrosis is common in Necrotrophy and Hemi-biotrophic bacteria as they use toxins to induce death in the cells and obtain nutrients from the dead cells. An example is *Xanthomonas citri* which uses T3SS to induce effectors coded by *pthA* genes that induced that regulate the phytohormones such as Auxins and gibberellins induce rapid cell division (Hyperplasia) and cell growth (Hypertrophy) and later on, the *pthA* proteins induce the programmed cell death to acquire nutrients resulting to swelling on the infected part and rupturing of epidermis appearing as raised corky-like necrotic lesions (Shahbaz et al., 2022; Kraepiel et al., 2016). Prasannath (2013) has also reported that, the pore-inducing toxins released by the phytopathogenic bacteria such as *Pseudomonas syringae* pv. Syringae which are syringomycins and syringopeptins have the role of inducing cell death (necrosis) due to their function of disrupting the cell plasma membrane and leakage of the cellular contents.

Vascular blockage

The damage caused by phytopathogenic bacteria, particularly those associated with the vascular tissues of plants, such as the xylem and phloem, blocks these crucial transport pathways. This blockage is primarily due to the activities of these bacteria within the vascular tissues, leading to a loss of turgor pressure and subsequent wilting symptoms characterized by the epinasty and collapse of leaves, stems, and other plant parts (Yadeta and Thomma, 2013). Seven major genera of bacteria affect plants' vascular tissues: *Clavibacter, Curtobacterium, Erwinia, Pantoea, Ralstonia, Xanthomonas*, and *Xylella* as indicated in Table 1 (Agrios, 2005; Yadeta and Thomma, 2013).

Table 1. Bacterial genera causing vascular blockage. Retrieved from Agrios (2005) and Yadeta and Thomma (2013)

Sl. No.	Genera	Species	Crop affected
1	*Clavibacter*.	*C. michiganense subsp. sepedonicum*	Potato
		C. michiganense subsp michiganense	Tomato
2	*Curtobacterium*.	*C. flaccumfaciens*	Common Beans.
3	*Erwinia*.	*E. tracheiphila*	Cucurbits
		E. amylovora	Pome fruits such as Apples
4	*Pantoea*.	*P. stewartii*	Maize
5	*Ralstonia*.	*R. solanacearum*	Solanaceae crops (Tomato and Potato) and Banana
6	*Xanthomonas*.	*X. campestris pv. campestris*	Crucifers.

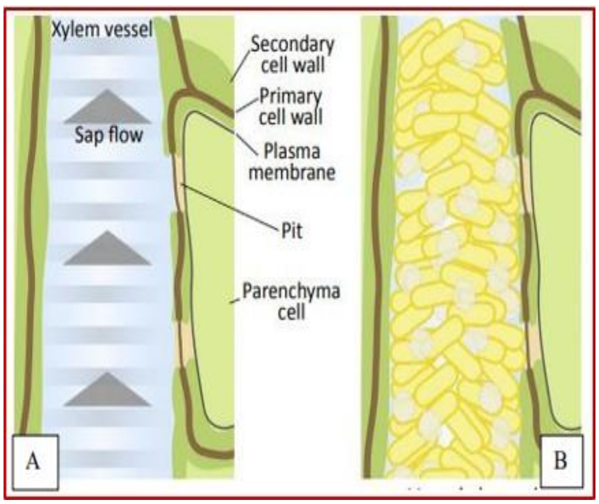

Figure 2. Vascular tissue from a healthy plant (A). Blocked vascular tissues due to Phytopathogenic bacterial EPS from a diseased plant (B). Retrieved from Lowe-Power et al. (2018).

These bacteria infect the xylem, colonizing the root xylem and producing a protective layer known as exopolysaccharides. These exopolysaccharides serve as a defensive shield against the plant's reactive oxygen species (ROS) and other defensive mechanisms and they act as an adherent or binding agent, helping the bacteria firmly attach to the host as the initial step of infection ((Benali et al., 2014; Carezzano et al., 2023). The accumulation of exopolysaccharides within the vascular system blocks the movement of water and nutrients the roots absorb to other parts of the plant, leading to the characteristic wilting symptoms (Ingel et al., 2022). As a significant virulence factor, exopolysaccharides are crucial for the pathogenicity of bacteria affecting the plant's vascular system as shown in Figure 2. The blockage of xylem vessels by these secretions disrupts the essential transport of water and nutrients, ultimately resulting in the severe wilting and decline of the infected plant.

Damage of photosynthetic pigments (Chlorosis)

Phytopathogenic bacteria release several types of pathogenic factors including toxins some of which have effects on the chlorophyll of the host plant leading to chlorosis of the plant vegetation. According to Pfeilmeier et al. (2016), Arnold et al. (2011), and Arvizu-Gómez et al. (2022), reported the role of toxins such as phaseolotoxin, mangotoxin, and tabtoxin that are secreted by pathovars of *Pseudomonas syringae* with an example of *Pseudomonas syringae pv. Phaseolicola is* a causative agent of halo blight in Common beans. The secretion of such toxins by phytopathogenic bacteria affects the synthesis of chlorophyll, a pigment responsible for the green color of plants' vegetation by the degradation of the chlorophyll and irreversible inhibition of Glutamate synthetase (GS) and ornithine carbamoyltransferase (OCTase) resulting in the interference with the nitrogen metabolism in the plant reducing the amount of free glutamate (Pfeilmeier et al., 2016; Guardado-Valdivia et al., 2021). Because glutamate is one of the crucial precursors of chlorophyll synthesis (Forde and Lea, 2007; Okumoto et al., 2016; Brzezowski et al., 2015), interference with its biosynthesis in the plant interferes with the biosynthesis of chlorophyll resulting in the appearance of a yellowing color on the leaves instead of green (Chlorosis).

Cell wall degradation

Apart from phytopathogenic bacteria secreting toxins through the secretory systems I and II (SS I and SS II), they also use similar secretory systems in the secretion of enzymes. Enzymes secreted by phytopathogenic bacteria include pectinase, cellulases, xylanases, amylases, and proteases (Benali et al., 2014; Pfeilmeier et al., 2016). Among the stated, pectinase is one of the most important enzymes that degrades and breaks down pectin, a component of the cell wall resulting in damage to cellular integrity and tissue maceration thus facilitating the entry of the bacteria inside the cell and exposing the cellular components including nutrients and organelles accessible to the bacteria (Fatima and Senthil-Kumar, 2015). According to Kohli and Gupta (2015), Sharma et al. (2013), and Agyemang et al. (2020), the reported various phytopathogenic bacteria that can secrete exoenzymes particularly pectinase such as *Dickeya dadantii* formerly known as *Erwinia chrysanthemi*, a causative agent of soft rot in an onion, *Agrobacterium tumefaciens*, a causative agent of crown gall disease, *Ralstonia solanacearum*, a causative agent of Potato Brown Rot, *Pseudomonas solanacearum*, a causative agent of Bacterial wilt, *Pectobacterium carotovorum* formerly known as *Erwinia carotovora*, a causative agent of soft rot and Blackleg in vegetables such as carrot and potato as illustrated in *Table 2*. The action of the pectinase enzyme on the cell wall is characterized by the disintegration of plant tissues, which become soft, watery, and slimy, accompanied by a foul odor from the rotting tissues (Agrios, 2005).

Table 2. Summary of Phytopathogenic bacteria that secretes Pectinase enzymes

Sl. No.	Bacterial species	Enzyme secreted	Crop affected	Source
1.	*Erwinia chrysanthemi*	Pectin methyl esterase, Polygalacturonase, and Pectate lyases.	Banana, Sorghum, Sweet potato, Tobacco.	Hugouvieux-Cotte-Pattat, N., & Shevchik, (2003).
2.	*Erwinia carotovora*	Pectate lyase, pectin lyase, Polygalacturonase	Potatoes, carrots, cabbage and beets	Naligama, & Halmillawewa (2022); Lingam et al. (2022).
3.	*Pseudomonas syringae* pv. Phaseolicola	Pectate lyase, Pectin methylesterase, and Polygalacturonase.	Common Beans	Hernández-Morales et al. (2009)
4.	*Ralstonia (Pseudomonas) solanacearum*	Polygalacturonases and Pectin methylesterase.	Banana, tomatoes, tobacco and Potato.	Peeters et al. (2013); Uwamahoro et al. (2020); Sahu et al. (2020).

Hormonal manipulation

Pathogenic factors of Phytopathogenic bacteria such as toxins and effectors have been reported to impart imbalance to the growth hormones of the host plants which benefits the Phytopathogenic bacteria in two major ways one being suppressing the defense responses of the host plant leading to the successful infection and colonization and another being taking over plant development as well as nutrient allocation for their survival in the host plant (Ma and Ma, 2016). An example as explained by Block and Alfano (2011), *Pseudomonas syringae* produces effectors such as HopI1 (Type 3 effector) that affect the Salicylic Acid (SA) production and accumulation thus affecting the plant defense mechanism as SA is one of the major phytohormones involved in the plant defense. Moreover, Hann et al. (2014) reported that phytopathogenic bacterial genera such as *Pseudomonas, Xanthomonas*, and *Ralstonia*, secretes HopQ1, a type 3 effector that activates the production of Cytokinin hormone as it activates the conversion of precursors of CK due to its hydrolytic activity that in return it reduces the suppression of FLAGELLIN SENSING 2 (FLS2) impairing the plant defense (Hann et al., 2014; Ma and Ma, 2016). Similarly, *Agrobacterium tumefaciens*, a causative agent of crown gall disease has effects on the phytohormones in the host plant. According to Gan et al. (2019) and Mashiguchi et al. (2019), after the attachment and penetration of the Agrobacterium tumefaciens through natural openings or wounds, it transmits a segment of its plasmid known as T-DNA or transfers DNA into the plant cell using the Type IV secretion system (T4SS), that becomes integrated with the plant's nuclear genome and alter the plant normal metabolic activities including encoding for the enzymes involved in the biosynthesis of plant hormones such as auxins and cytokinin. These hormones are crucial for plant cell division and growth. The overproduction of auxins and cytokinin leads to uncontrolled cell division resulting in hypertrophy, hyperplasia, and gall formation.

Indirect damage of Phytopathogenic bacteria on the host plant

The activities of pathogenic phytopathogenic bacteria in the plant and secretion of pathogenicity factors such as enzymes, toxins, and Type III effectors result in damage to the cell membrane, and cell wall, induce cell death (necrosis), vascular blockage, cell photosynthetic pigments and hormonal imbalance that consequently reduce plants' assimilation ability, death of organs or complete plants, and malformation and growth reduction.

Reduction of assimilating by yellowing and necrosis

Effects of phytopathogenic bacteria on photosynthetic pigments (Chlorosis) and induction of cell death (Necrosis) reduces the ability of the plant to photosynthesize its food due to the reduction of photosynthetic pigments and the leaf surface area. *Pseudomonas syringae pv. Phaseolicola* is a good example of a phytopathogenic bacteria that affects the ability of the plant to synthesize its food due to the secretion of phaseolotoxin that impairs chlorophyll biosynthesis (Pfeilmeier et al., 2016, Arnold et al., 2011, and Arvizu-Gómez et al., 2022). Another example is *Xanthomonas citri* which induces a cell-programmed death resulting in necrosis and reduction of the leaf surface area for photosynthesis (Shahbaz et al., 2022; Kraepiel et al., 2016). A similar case is reported on *Xanthomonas axonopodis* pv. *Glycines* on Soybean, whereby the phytopathogenic bacteria induces necrosis on plant foliage that under favorable conditions can expand to large necrotic lesions resulting in premature leaf defoliation and finally reduction of the photosynthetic leaf area (Darrasse et al., 2013). In a study conducted by Huliaieva et al. (2022) on the impact of *Xanthomonas axonopodis* pv. *Glycines* on Soybean photosynthesis, it was discovered that the bacteria could lead to an 11.8% reduction in the maximum quantum efficiency of PSII (Fv/Fm), signifying that phytopathogenic bacteria can significantly impair the plant's ability to manufacture its food. The reduced photosynthesis and food assimilation result in reduced plant growth and quality and quantity of crops. Because the induction of the plant disease is cost-intensive in terms of nutrients (Berger et al., 2007; Swarbrick et al., 2006), the reduction of assimilates makes the plant fail to induce defensive actions thus becoming more susceptible not only to the phytopathogenic bacteria associated with it but also other multiple infections from other phytopathogens.

Death of organs or whole plants

Phytopathogenic bacterial infection can cause the death of plant organs or the complete death of the plant. This results from the secretion of pathogenicity factors such as toxins and enzymes that impair the metabolic activities of the plant and cellular integrity and ultimately cause cell death. This is true, especially for necrotrophic phytopathogenic bacteria such as soft rot pectinolytic bacteria including Erwinia spp. that secretes plant cell wall-degrading enzymes (PCWDEs) through the type II secretion system (T2SS) such as pectin, protease, and cellulase that macerating host tissues and in obtaining nutrients from dead cells (Kraepiel and Barny, 2016; Joshi et al., 2024). A similar case is observed in hemibiotrophic pathogenic bacteria such as *Xanthomonas citri*, a causative agent of the Bacterial Citrus Canker, that uses T3SS to induce effectors coded by *pthA* genes that induced that regulate the phytohormones such as Auxins and gibberellins induce rapid cell division (Hyperplasia) and cell growth (Hypertrophy) and later on, the *pthA* proteins induce the programmed cell death to acquire nutrients resulting to swelling on the infected part and rupturing of epidermis appearing as raised corky-like necrotic lesions (Shahbaz et al., 2022 and Kraepiel et al., 2016) in which an extended cellular death result into the death of plant tissues and plant organs.

Apart from the bacteria that cause organ and plant death due to the induction of cellular death, pathogenic bacteria that utilize vascular tissues such as phloem and xylem as the nutrient niche interferes with the translocation of the nutrients and photosynthates due to blockage of the conductive tissues (Ingel et al., 2022; Vinatzer, 2012). Agrios (2005) and Yadeta and Thomma (2013) have mentioned several phytopathogenic bacteria genera to be associated with the vascular wilts of various crops which are *Clavibacter, Curtobacterium, Erwinia, Pantoea, Ralstonia,* and *Xanthomonas*. This blockage of translocation of nutrients and water that can be caused by the production of the Exopolysaccharides (EPS) by the vascular wilt bacteria results in drooping, wilting, and ultimately the death of aboveground parts of the host plant (Agrios, 2005).

Malformation and growth reduction

The malformation is one of the characteristic damages associated with phytopathogenic bacteria. The ability of some bacteria to manipulate host plant phytohormones such as cytokinin and auxins has resulted in malformation and growth reduction damage. This is evident in root galls resulting from the *Agrobacterium tumefaciens* and according to Gan et al. 2019 and Mashiguchi et al. (2019), the bacteria induce the production of auxin and cytokinin by the influence of enzymes that are coded by bacterial plasmid known as T-plasmid. The overproduction of particular phytohormones results in rapid and irregular cell division can be observed as galls on the roots of the infected host plant as shown in Figure 3. The resulting galls produce nutrients known as opines that are used by the bacteria (Flores-Mireles et al., 2012; Faist et al., 2023) but at the same time the affected roots lose their ability to absorb water and minerals affecting the growth of the plant (He et al., 2021).

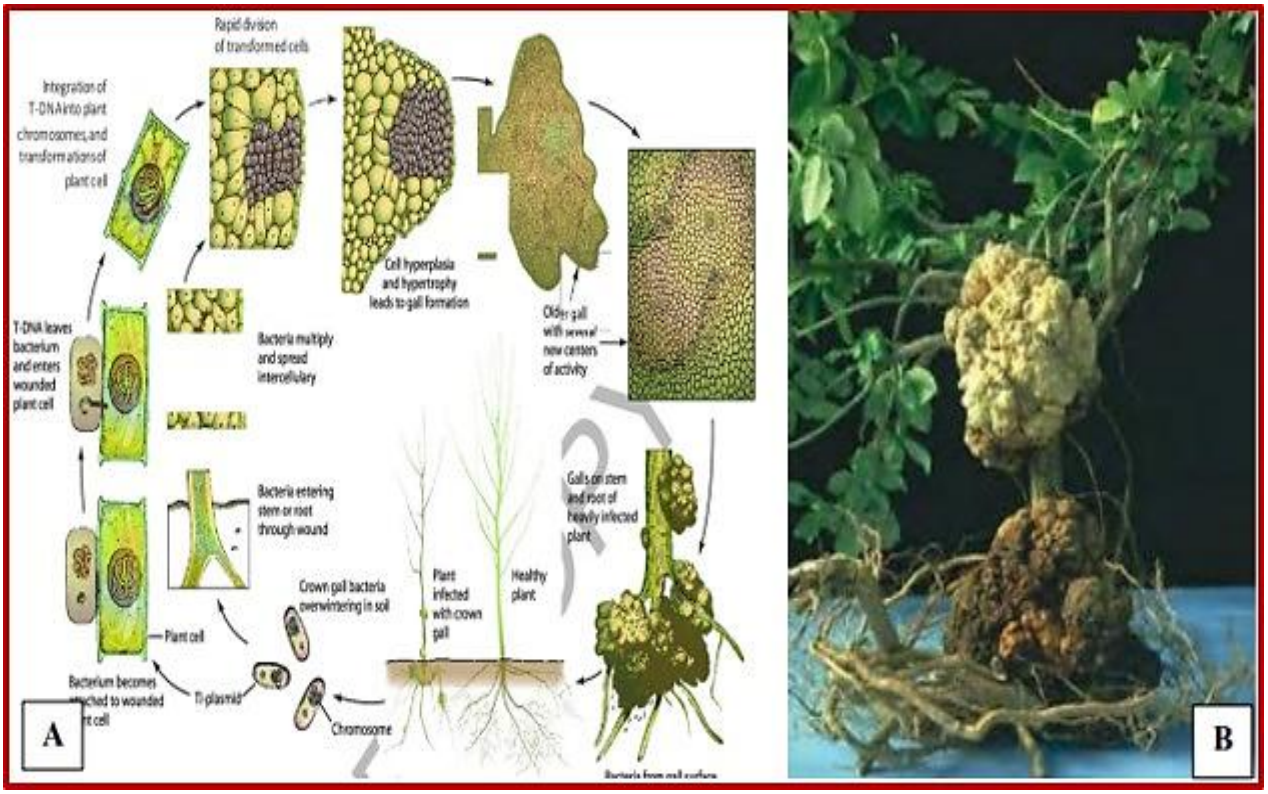

Figure 3. Crown gall disease caused by *Agrobacterium tumefaciens*. Life cycle of Agrobacterium tumefaciens (A). Galls formation due to Agrobacterium tumefaciens (B). Source: Agrios (2005).

Losses due to Phytopathogenic bacteria

Agrios (2005) recognized three main types of losses that can be caused by any plant pathogens which are yield losses, quality losses, and financial losses. In the context of Phytopathogenic bacteria, similar types of losses are discussed in this section.

Yield losses

Due to the damage the pathogenic bacteria impart on plant metabolism and physiology including cellular division, photosynthesis, water uptake, and translocation of photosynthates, the expected normal growth and productivity of the crop are compromised. The actual yield losses caused by bacteria vary with the Phytopathogenic bacterial species, geographical location, and the crop affected with the highest reported to reach up to 100% if not timely managed as indicated in Table 3.

Economic Losses

Agrios (2005) explained the various ways pathogenic diseases can lead to economic or financial losses. These include the necessity for farmers to cultivate crops using expensive resistant varieties, the costs incurred for managing diseases in both pre-harvest and post-harvest stages, rejection of agricultural produce due to poor quality, and loss of yield, all of which reduce the net returns. In the context of phytopathogenic bacteria, the economic loss is reported to be over 1 USD billion annually (Vicente et al., 2022; Islam et al., 2024; Kannan et al., 2015). However, the actual economic loss varies widely depending on various aspects such as the type of crop affected and the phytopathogenic bacterial species in question as indicated in Table 4.

Table 3. Yield loss caused by phytopathogenic bacteria

Sl. No.	Phytopathogenic bacteria	Country	Crop	Yield loss	Reference
1.	*Ralstonia solanacearum*	East and Central Africa	Round Potato	50-100%	Munyaneza and Bizimungu (2022)
		Uganda	Tomato	88%	Wang et al. (2023)
		India	Round potato	2-95%	Islam et al. (2024)
		China	Tomato	10-80%	Wei et al. (2017
			Round Potato	10-100%	Jiang et al. (2017)
			Tobacco	15-75%	Jiang et al. (2017)
		Nigeria	Tomato	60-100%	Popoola et al. (2015)
		Ethiopia	Ginger	80-100%	Guji et al. (2019)
			Round Potato	30-90%	Tessema and Seid (2023)
			Tomato	100%	Wang et al. (2023)
2.	*Pseudomonas syringae.*	Australia	Zucchini	70-80%	Djitro et al. (2022)
		Mexico	Wheat	5-20%	Valencia-Botín and Cisneros-López (2012)
		Ontario, Canada	Tomato	60%	Lonjon et al. (2024)
		South Africa	Dry Beans	55%	Muedi et al. (2015)
		China	Dry Beans	50%	Sun et al. (2017)
		Brazil	Coffee	70%	Zoccoli et al. (2011)
3.	*Xanthomonas spp.*	East Africa	Common Beans	10-40%	Fininsa and Tefera (2001)
		East and Central Africa	Banana	80-100%	Geberewold (2019)
		India	Rice	2-74%	Rajarajeswari and Muralidharan (2006)
		India	Grapes	60-80%	Ferreira et al. (2019)
		India	Cotton	30-35%	Saini et al. (2024)
		Brazil	Cassava	30-100%	Aquiles et al. (2021)
		Asia (Bangladesh)	Rice	14.9-50%	Nugroho et al. (2022)
		Iran	Cotton	10- 30%	Razaghi et al. (2012)
4.	*Erwinia spp.*	China	Apple and Pear	30-50%	Sun et al. (2023)
		China	Banana	82%	Zhang et al. (2014)
		India	Maize	98.8%	Kumar et al. (2017)
		Zimbabwe	Round Potato	20-60%	Ngadze et al. (2010)

		Indonesia	Papaya	100%	Suharjo et al. (2021)
5.	*Agrobacterium tumefaciens*	Kenya	Roses	60%	Njagi et al. (2021)

Table 4. Summary of economic losses caused by different phytopathogenic bacteria in various crops worldwide.

Sl. No.	Pathogen	Crop	Economic loss (USD)	Reference
1.	Ralstonia solanacaearum	Round Potato.	848 million	Wang et al. (2023)
2.	*Pectobacterium spp* and *Dickeya spp*	Round potato.	50 million	Islam et al. (2024)
3.	Erwinia papayae	Papaya.	58 million	Maktar et al. (2008)
4.	*Erwinia amylovora*	Apple and Pear	42 million	Borruso et al. (2017)
4.	Xanthomonas campetris pv. *Musacearum.*	Banana.	2-8 billion	Nakato et al. (2018); Onyambu et al. (2021)
5.	*Xanthomonas citri* pv. *mangiferaeindicae*	Mango	1 million	Sossah et al. (2024)
6.	Xanthomonas hortorum	Tomato	7-8 million	Dia et al. (2022); Rotondo et al. (2022)
7.	Pseudomonas syringae pv. Actinidiae.	Kiwifruit	885 million	Wang et al. (2023).
8.	Xylella fastidiosa	Grapes	104.4 million	Buttimer et al. (2017)

Quality loss

The infection of the phytopathogenic bacteria with the secretion of pathogenicity factors not only affects the productivity of the plants in terms of quantity of yield but also affects the quality of the crop that is produced. For example, Bacterial specks of Tomato caused by *Pseudomonas syringae* pv. *Tomato* that is characterized by raised, flat, or sunken black spots on tomato fruit, have resulted in loss of fruit quality attribute of appearance making them less preferrable in the market (Shenge et al., 2010). Similarly, Bacterial soft rot in Potato that is caused by *Pectobacterium carotovorum*, reduces the tuber quality by affecting the appearance of the tuber due to rotting with a watery appearance and smell as the soft rot is associated with the emission of foul odor making the product not preferable to the market (Agrios, 2005; Hadizadeh et al., 2019). *Pantoea agglomerans* pv. *Betae*, a causative agent of tubercle disease of sugar beet, is characterized by the formation of galls on the beetroots (Geraffi et al., 2023). The disease distorts the appearance of the sugar beets by forming galls on the surface of the beets affecting the quality of the beet and its market appearance. Moreover, the disease significantly reduces the sugar content of the beet by 1–1.5% and up to 3–6% when compared with the healthy beets, thus affecting the biochemical content of the beets (Nabrdalik and Moliszewska, 2023; Moliszewska et al., 2018). Apart from affecting the quality of agricultural produce, bacterial diseases also interfere with the quality attributes of seeds, which are crucial agricultural inputs. Thind (2020) has reported that the infection of *Pseudomonas syringae* pv. *Glycinea*, a causative agent of bacterial blight in soybean, reduces soybean seeds' quality by reducing their germination percentage to 68%.

CONCLUSION

Phytopathogenic bacteria damage host plants directly at the cellular level and indirectly compromise hosts' physiology and metabolism. Cellular disruption leads to reduced crop productivity resulting in yield losses, economic losses, and quality losses. This provides evidence that Phytopathogenic bacteria can cause substantial damage that cannot be ignored and justifies the need for bacterial disease management. Several management choices are available including the use of resistant varieties, crop rotation, plant nutrition, and destruction of debris. Future works should focus on improving the management practices in areas such as developing packages of Integrated Pest Management (IPM), establishing Economic Injury Levels (EIL), and incorporating advanced technologies of Smart Agriculture such as Machine learning, Unmanned Aerial Vehicles (UAV), and Internet of things technologies that can improve management of phytopathogenic bacteria through pathogens' identification and disease occurrence prediction that are initial important steps in any effective management of Phytopathogenic bacteria.

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AUTHOR CONTRIBUTIONS STATEMENT

Mulungu, E. L. solely contributed to this review.

CONFLICTS OF INTEREST

There is no competing interest to declare.

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ETHICS APPROVAL

Not applicable

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