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Review Article

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Phytopathogenic bacteria associated with vegetable crops in the Tropics

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ABSTRACT

Vegetables are among the most important crops in Southeast Asian countries, including the Philippines. Bacterial pathogens are among the most important constraints in vegetable production, causing destructive diseases. This paper provides an overview of bacterial diseases of vegetable crops in the Philippines. Here, we focus on the pathogens associated with these diseases and highlight interventions done globally to mitigate the diseases' impact on vegetable production. Phytopathogenic bacteria are associated with ten plant diseases in the Philippines. These are bacterial wilt (*Ralstonia solanacearum* species complex), bacterial soft rot (*Pectobacterium carotovorum*), bacterial leaf spot (*Xanthomonas campestris* pv. *vesicatoria*), black rot (*Xanthomonas campestris* pv. *campestris*), bacterial fruit blotch (*Acidovorax avenae* subsp. *citrulli*), angular leaf spot (*Pseudomonas syringae* pv. *lachrymas*), common scab (*Streptomyces scabiei*), bacterial speck (*Pseudomonas syringae*), bacterial canker (*Clavibacter michiganensis*), and tomato pith necrosis (*Pseudomonas corrugata*). Using pathogen-free seeds, field sanitation, removal of weeds and alternate hosts, immediate removal of infected plant parts, and regular disease monitoring can aid in minimizing losses due to bacterial diseases. Finally, critical areas for future research to increase the understanding of vegetable diseases in the country and improve their management strategies are briefly discussed.

KEYWORDS: *Ralstonia* spp., *Xanthomonas* sp., *Pseudomonas* spp., Tomato, Solanaceous

INTRODUCTION

Vegetables are the second most important crop, after rice, among Southeast Asian countries. The vegetable production area is estimated at 60,000 ha in the Philippines alone, with an annual production of about 252,000 tons. This production includes tomato, which accounts for 218.8 metric tons (mt), potato at 537.3 mt, eggplant at 241.9 mt, and cabbage at 122.5 mt. These vegetables are valued at 3.58 billion, 8.54 billion, 5.13 billion, and 2.13 billion pesos, respectively (Philippines Statistics Authority, 2018).

Diseases caused by plant pathogenic bacteria are among the most significant constraints in vegetable production (Charkowski *et al.*, 2020) and are more severe in an environment that is warm and humid. Bacteria enter through wounds, incited either mechanically or by activities of other pathogens, and through natural openings of the plant. Thus, pre- and post-harvest vegetable handling and management are important in bacterial disease development and management. Bacterial pathogens also infect hosts, e.g., weeds, which allow the pathogens to survive without the primary host plant. Environmental factors (temperature, rainfall, and relative humidity) influence bacterial disease development. Under favorable conditions, and without control strategies, these bacterial diseases can cause severe infection in the field, significantly damaging the crop and reducing yield. Plant diseases, including those caused by bacteria, account for 40 to 50% of vegetable production losses in the Philippines (Pantastico, 1975; Estigoy, 2006).

Among the earliest records of bacterial pathogens affecting vegetables in the country was in 1918 (Reinking, 1918). Tangonan, (1999) lists the hosts of bacterial pathogens in vegetable crops in the country until 1999. However, no synthesis or review on bacterial diseases of vegetable crops in the country has been published, and those reported after the 1999 host index are yet to be included. This paper provides an overview of the bacterial diseases of vegetable crops in the Philippines. Here, we focus on the pathogens associated with these bacterial diseases and highlight interventions made in the country and globally to mitigate the diseases' impact on vegetable production. We then briefly discuss areas for future research to increase the understanding of vegetable diseases and improve their management strategies. While bacterial pathogens of interests are those recorded in the country, we included current understanding on the biology and epidemiology of the diseases (and their pathogens) that have been published elsewhere.

BACTERIAL WILT

Bacterial wilt was among the first bacterial diseases reported in the country (Reinking, 1918). This disease is caused by the *Ralstonia solanacearum* species complex. Both *R. pseudosolanacearum* and *R. solanacearum* have been reported in the country (Cueva *et al.*, 2019). Bacterial wilt is characterized by the sudden wilting of foliage from the tip or youngest leaf. In the Philippines, 19 plant species have been recorded as hosts of *R. solanacearum*, including banana, pepper, eggplant, tomato, and potato (Tangonan, 1999). The Philippines' bacterial wilt incidence in individual fields was up to 95% (Opina & Miller, 2005). Agati (1949) projected losses on tomato, eggplant, pepper, and tobacco in Central Luzon to be 80-95, 30-80, 10-40, and 10-50%, respectively. Crop losses in the Philippines brought by bacterial wilt-infested fields consistently reached 30 to 80% (Miller *et al.*, 2005). Nevertheless, yield loss could reach 100% when favorable environmental conditions and the planted crop variety are very susceptible (Elphinstone, 2005). The diversity of *R. solanacearum* species complex (RSSC) strains complicates the development of universal control methods (Ivey *et al.*, 2007).

Epidemiology

High soil moisture is linked to increasing disease incidence in the field, and entry of the bacterium into the host plant is through root injuries and natural openings (Charkowski *et al.*, 2020). The blocking of the vessels initiates the wilting of water and dissolved nutrients that cannot pass through the vessels. The stems of BW-infected plants show brown discoloration (Gota, 1992). The bacterium enters roots through wounds caused by farming operations, soil microfauna, and natural openings (Kelman & Sequeirra, 1965). When cut crosswise and dipped in clear water, the infected stem exudes viscous ooze (Champoiseau *et al.*, 2009b), a sign distinguishing bacterial wilt from Fusarium wilt (caused by a fungus). The bacterium grows as raised, fluidal, pinkish colonies in the tetrazolium chloride agar medium (Cueva *et al.*, 2019).

Management

In the Philippines, cultural management practices, such as mulching and reduced soil cultivation, have not significantly reduced bacterial wilt incidence (Miller *et al.*, 2005). Various control strategies were studied and developed to control and suppress this disease, including cultural, biological, and chemical control. Unfortunately, there is still no complete control over bacterial wilt disease. Breeding for resistance remains the most effective control method for bacterial wilt (Balatero *et al.*, 1999, 2000, 2001; Raymundo, 2001).

BACTERIAL SOFT ROT

Bacterial soft rot of vegetables is commonly caused by *Pectobacterium carotovorum* pv. *carotovorum* (formerly *Erwinia carotovora* subsp. *carotovora*). This bacterium is considered the most important and widespread bacterial soft rot pathogen of brassicas, carrots, celery, pepper, tomato, and potato (Daengsubha, 1980), which continues to cause losses for the Philippine vegetable industry (Bayogan *et al.*, 2009). The soft rot pathogen attacks crops in the field and post-harvest (Bayogan *et al.*, 2009). Symptoms start as small water-soaked lesions that enlarge rapidly, resulting in soft tissues and some fluid exuding from the infected part. Stems and petioles may become hollow due to the rapid dissolution of the pith and, in some severe cases, result in the collapse of plants (Janse, 2005). The infected tissues show a soft and slimy appearance and a foul odor. In cauliflower and cabbage, heads fail to form and are followed by stump rot. The lower parts of the stem become stunted and wilted in carrots, later causing the plant's death.

Epidemiology

The bacteria enter the plant tissue primarily through wounds. Relatively high temperatures (Gesmundo & Natural, 1989; Barbin *et al.*, 2015), high relative humidity, and a wet environment (Barbin *et al.*, 2015) worsen the infection. The bacterium adheres to the infected tissues in storage, plant debris in the soil, and other hosts. It spreads when present externally on the seed. Insects and their larvae can distribute and transmit the bacterium (Kloepper *et al.*, 1979). Besides, farm machinery, irrigation water, and rain can also distribute the bacterium efficiently, and it has been reported that it can seldom survive in surface water (Perombelon, 1980; Pérombelon & Hyman, 1987; Pérombelon, 2002). Soft rot remains an economically significant disease most prevalent in warm and humid climates. Farmers lose millions annually to bacterial soft rot, which can occur during storage and marketing.

Management

Bacillus sp. and actinomycetes inhibiting *P. carotovorum* have been reported (Aspiras, 1986). Low soft rot incidence was observed in brassicas, tomatoes, and potatoes when the bio-organic fertilizers "Effective Microorganisms" and Bokashi were applied (Escano, 1996). Some medicinal plants (*Allium porrum*, *Euphorbia tirucalli*, *Gynura procumbens*, & *Piper betel*) were also found to have antibacterial activities against the pathogen (Lirio *et al.*, 1998; Alcedo *et al.*, 2000; Benitez & Benitez, 2018). Alum dissolved in water and applied by brushing, wiping, or spraying was also proven effective in preventing soft rot development (Geronimo, 1984; Estrada *et al.*, 1988; Aquino-Nuevo & Apaga, 2010). Using alum spray and newspaper wrapping also reduced disease incidence (Bayogan *et al.*, 2009). Nonetheless, preventing damage by properly handling vegetables is paramount to avoiding wounds, which will serve as entry points for the bacterium.

BACTERIAL LEAF SPOT

The bacterium *Xanthomonas campestris* pv. *vesicatoria* (syn. X. *axonopodis* pv. *vesicatoria)* causes bacterial leaf spots and primarily affects solanaceous and cucurbits, including cucumber, pumpkin, lettuce, tomato, and pepper. Symptoms first appear as small, circular, pale green pimples raised on the underside of the leaf. On older leaves, spots are dark green and water-soaked, and longitudinal spots with a scabby appearance with cracks can be observed on stems and petioles. In fruits, spots are conspicuous, circular, green but brown, and raised with cracked, roughened, and wart-like surfaces. Also, spots may serve as an entry for secondary rotting organisms.

Epidemiology

The bacteria have limited survival in the soil; hence, they may be found on debris from infected or diseased plants. Volunteer tomato and pepper plants are potentially important inoculum sources. The pathogen can survive in the seed and exhibit lesions soon after emerging from the soil. The bacterium can be spread by overhead irrigation, which causes the leaf spots to expand, lose their circular form, and finally affect the whole leaf. Affected leaves appear blighted or scorched. Early research also reported that bacterial spot pathogens might be seed-borne (Gardner, 1923). However, its transmission as an initial inoculum has not yet been established (Cox *et al.*, 1956; Goode & Sasser, 1980; Marco & Stall, 1983). Commercial seeds are usually surface sterilized with bactericides to reduce contamination. However, the low incidence is still important in introducing the pathogen (Stall *et al.*, 2009).

Bacterial spot is a devastating disease of pepper and tomato worldwide (Jones *et al.*, 1998). It may result in total crop loss when it occurs soon after transplanting, and prevailing conditions remain favorable for disease development. For instance, losses in tomato production in Florida were $3,090 per acre in 2008, and in processing were $7-8 million in 2010. However, losses in vegetable crops due to bacterial leaf spots are yet to be determined.

Management

Diseases caused by *Xanthomonas* spp. can be managed by proper cultural practices and crop management, including proper plant density and spacing, correct rate, time, and several fertilizer applications, cropping systems, field sanitation, and good water management, and resistant cultivars (Mew & Natural, 1993). In addition, McDougall *et al.* (2019) reported that organic soil amendments using cabbage residues, *Chromolaena odorata*, and forest leaf litter could significantly reduce tomato bacterial spot incidence.

BLACK ROT

The bacterial pathogen *X. campestris* pv. *campestris* (*Xcc*) causes black rot on brassicas, including cabbage, broccoli, kale, cauliflower, and pechay. Its earliest report in the country was on Brussels sprouts (Reinking, 1918). Symptoms appear as yellow and V-shaped lesions with blackened veins at leaf margins and enlarge toward the leaf base and later enlarge, become brown and necrotic, papery, and may cover the whole leaf, wilt, and die. This disease spreads on seeds and is the primary source of inoculum for infection. The bacterium is transmitted in the seed (Kim, 1986). It can survive in diseased plant debris. The bacterium could survive in the soil, independent from the host, for 20-40 days (Dane & Shaw, 1996). The bacteria can disperse over short distances through the wind, insects, irrigation water, rain, and farm equipment. An overhead irrigation system can significantly increase the dissemination of the bacterium.

Epidemiology

The extent of loss in vegetable production in the country due to black rot has not been well documented. However, in other countries, the disease contributes to losses ranging from 23% (Djalilov *et al.*, 1989; Gupta, 1991; Shiomi, 1992; Mguni, 1996; Bila *et al.*, 2009) depending on the crop.

Management

Copac E has significantly reduced cabbage's black rot infection. Like the bacterial leaf spot, black rot can be managed (or mitigated) by proper cultural practices and crop management, proper plant density and spacing, correct rate and time of fertilizer applications, cropping systems, field sanitation, good water management, and resistant cultivars (Mew & Natural, 1993).

BACTERIAL FRUIT BLOTCH

Acidovorax avenae subsp. *citrulli* (syn. *Pseudomonas avenae* subsp. *citrulli*) commonly causes bacterial fruit blotch (BFB) and affects various cucurbits. Cucurbit seedlings primarily observe symptoms, including water-soaking on the cotyledons' undersides and damping off. BFB causes greasy-like lesions that progress even in dry conditions. Dark reddish-brown to tan, angular spots that coalesce can be observed in the leaf veins, extending along the stems and true leaves' tissues (Walcott, 2005). On fruits, the disease initially appears as small, olivaceous, irregular lesions on the surface that expand and coalesce into large blotches, resulting in cracking of the affected area (rind cracking) and exuding of yellowish-brown liquid from the fruit tissues (internal fruit rot) (CABI, 2022a).

Epidemiology

Direct planting of infested seeds under high relative humidity, high temperature, and high population results in BFB seedling transmission and rapid disease spread. Other possible inoculum sources include volunteer seedlings, cucurbit weeds, and decaying infested debris.

Management

BFB has great potential to cause significant economic losses to cucurbit production, with up to 90% of marketable yield losses reported (Walcott, 2005). In Brazil, yield losses are estimated at 40-50% but might reach 100% (EPPO, 2010). It threatens the UK in cucumber production, where relatively small yield losses can result in substantial economic losses (Parkinson, 2014). Excluding primary inoculum, proper cultural practices, and using copper-based bactericides can help manage BFB. Effective disease management should be practiced in seed and transplant production.

ANGULAR LEAF SPOT

The bacterial pathogen *Pseudomonas syringae* pv. *lachrymas* cause an angular leaf spot on vegetables and are the most widespread bacterial disease of cucurbits (Zitter *et al.*, 1986). Symptoms initially appear as small, water-soaked spots on leaves with a shallow white-yellow to brown halos, becoming angular and eventually coalescing. Infections later turn brown, dry, and drop out. Water-soaked spots on fruits also form star-like cracks, yellowish gum, and slime exudates in advanced stages (Aglave, 2018; Goss, 1964).

Epidemiology

Angular leaf spot is a seed-transmitted disease (Leben, 1981). The bacterium can survive for more than a year on plant debris (de Gotuzzo, 1976), and means of dispersal include rain, wind, insects and birds, and cultural activities, e.g., using machines and irrigation water (Kritzmann & Zutra, 1983). High plant populations combined with dense spacing, humid conditions, and overhead irrigation also contribute to disseminating the pathogen and spread of the disease. Early infection results in a substantial yield reduction (Pohronezny *et al.*, 1977).

Management

Proper cultural practices and crop management, including the use of pathogen-free seeds, dry soil cultivation (Kritzmann & Zutra, 1983), proper plant density and spacing, correct rate, time, and several fertilizer applications, crop rotation for at least two years, field sanitation, good water management, and resistant cultivars (e.g., Krivchenko & Medvedeva, 1985; Medvedev & Medvedeva, 1989) are measures that will help control the disease and avoid the disease's loss (Hansen, 2009). In addition, the application of copper-based sprays (e.g., cupric hydroxide) as foliar protectants (Mabbett & Phelps, 1984) and fungicide mixtures has also been found to be adequate in controlling the disease.

COMMON SCAB

Common scab is caused by *Streptomyces scabiei* (Thaxter, 1892; Lambert & Loria, 1989b) on vegetables and root crops (Goyer *et al.*, 1996) and on peanut pods (Kritzman *et al.*, 1996). Potato is the most economically important host of *Streptomyces* species, which causes necrosis on potatoes' belowground roots, stolons, and stems (Charkowski *et al.*, 2020). In addition, the common scab is often associated with another scab disease, powdery scab, caused by the plasmodiophorid pathogen *Spongospora subterannea* (Balendres *et al.*, 2016; Balendres & Masangcay, 2020). The scabs produced by the latter are often raised. When the pustules burst, powdery structures containing the sporosori (or conglomerates of spores) can be observed.

Epidemiology

Streptomyces scabiei has a comparatively different life cycle than many bacterial pathogens. It grows as filamentous mycelia-like cells. Pathogenic *S. scabiei* subsists and disseminates primarily through spores, which can spread in water by soil-dwelling invertebrates (e.g., worms, isopods, millipedes), infected root tissue in the soil, and seed tubers. *S. scabiei* spores are heat-resistant and can thrive in the soil for 20 or more years. It passes through the plant tissues and tubers in natural openings, i.e., wounds and lenticels (Lapwood, 1973; CABI, 2022b).

Management

Common scabs can cause total loss associated with mishandling and poor cultural production practices, e.g., too much lime application. This disease reduces tuber quality and yield loss (Hill & Lazarovits, 2005). Management of *S. scabiei* is done through planting tolerant cultivars, if available. Maintaining good soil moisture with proper water management (Davis *et al.*, 1974a, 1976; Adams *et al.*, 1987). Keeping soil pH levels low (at 5.2) and applying sulfur, ammonium sulfate, and gypsum, which are acid-forming nitrogen fertilizers, effectively reduces the severity of the disease (Davis *et al.*, 1974b; Mizuno *et al.*, 1995). Practice crop rotation of non-host crops for at least three years to lessen the inoculum in the soil (Aglave, 2019; CABI, 2022b).

BACTERIAL SPECK

Bacterial speck disease is caused by *Pseudomonas syringae* pv. *tomato*. It is an economically important disease of tomato. *P. syringae* pv. *tomato* causes small, round, green, dark water-soaked spots with a narrow yellow halo on true leaves, turning to grey-black or brown and necrotic with a narrow yellow halo (Goode & Sasser, 1980; Janse, 2005). Fruit infection can lead to an infestation of tomato seeds.

Epidemiology

P. syringae pv. *tomato* persists primarily in plant debris and as a leaf epiphyte on symptomless tomato plants and weeds. *P. syringae* pv. *tomato* is seed-transmitted and can thrive for a long time in/on seed (over 20 years) (Chambers & Merriman, 1975; Aglave, 2019). Means of spread include rain splash and machinery, and survival in the soil over long periods (Schneider & Grogan, 1977; Bashan *et al.*, 1978).

Management

Bacterial specks on tomatoes occur in all tomato-producing areas of the world. Yield loss occurs because of reduced photosynthetic leaf area and fruit lesions, accounting for 75% loss in early infected plants (Yunis *et al.*, 1980). Outbreaks can also occur, inflicting severe damage to tomato plants. They can reduce crop yields and fruit quality (Goode & Sasser, 1980). Fruit infection can lead to an infestation of seeds. Management of bacterial speck starts with the use of disease-free seeds with seed treatment (i.e., *streptomycin sulfate*, *hypochlorite*) (Pyke *et al.*, 1984) Siviero, (1991) and hot water treatment (Devash *et al.*, 1979; Ivey *et al.*, 2005; Mtui *et al.*, 2010) and planting of healthy transplants. Avoid planting in an area previously infected with the disease for at least two years, and remove alternate hosts, i.e., weeds and volunteer plants (CABI, 2022c).

BACTERIAL CANKER

Bacterial canker of solanaceous crops is commonly caused by *Clavibacter michiganensis* pv. *michiganensis* is one of the most destructive diseases of tomato and pepper worldwide and has been reported on tomatoes in Southern Philippines (McDougall *et al.*, 2019). Symptoms cause stunting, wilting, vascular discolorations, canker on stems, and fruit lesions. First, it appears on older leaves, which turn downward, leaflets curl and finally shrivel. Characteristic coloration inside affected stems can be found by cutting the stem vertically. The tissue is first creamy white to yellow and later reddish-brown. Infected fruits, when they are young, become stunted and distorted. In contrast, late-infected fruit has no external symptoms except that the calyx scar is discolored. Initially, fruit spots are small, round, white, and slightly raised. The latter center becomes pustular, breaks open, has a rough yellow-brown surface, and has a white halo, resulting in a "bird's eye spot" (Gleason *et al.*, 1993; Sen *et al.*, 2015; Aglave, 2019).

Epidemiology

This is a seed-borne disease and can also persist in plant debris, weed hosts, and contaminated farm equipment/ tools (for example, seed cutters, transport vehicles, etc.) and contaminated stores and containers. It spreads between areas by splashing water from rain or overhead, sprinkler irrigation, and other cultural activities. While plant-to-plant spread is usually minimal, insects may transmit the disease. It can remain infectious in the dried state for at least 18 months at 5 to -40 °C temperatures.

Management

Twenty to 70% yield losses have been recorded in France and the USA. Management of bacterial canker is achieved mainly through the strict implementation of quarantine measures and following seed certification (Charkowski *et al.*, 2020). In addition, the practice of crop rotation, disinfection, and sanitation practices (i.e., cleaning equipment, disposing of and plowing, and burying under all plant debris immediately after harvest) is essential whenever it occurs to prevent the disease's recurrence and spread of the pathogen. Control of volunteer crops and solanaceous weeds, clean seeds, sterilized growing media, and healthy transplants are also vital in managing the disease (Aglave, 2019).

TOMATO PITH NECROSIS

Several *Pseudomonas* species cause tomato pith necrosis *viz.*, *Pseudomonas corrugata*, *P. cichorii*, *P. fluorescens*, *P. marginalis*, *P. mediterranea*, and *P. viridiflava* (Alivizatos, 1986; Saygili *et al.*, 2008; Trantas *et al.*, 2013, 2015) worldwide and recently reported in the Philippines (McDougall *et al.*, 2019). The characteristic symptom of the disease is necrosis or hollowing of the stem pith. The disease exhibits the loss of the plant's turgidity, white or dark but hard and necrotic areas near the xylem, disaggregation due to ladder-like formation of cavities, and numerous adventitious roots on numerous stems. The disease is initially observed from the stem's base and works up to the leaf stems and bunches. The pith is dark brown and water-soaked but not soft.

Epidemiology

Pseudomonas corrugata is soil-borne and can survive in soil (Scortichini, 1989; Kritzmann, 1990) and in the rhizosphere of the host plant species (Pandey *et al.*, 2000). The entry point of the pathogen is through the stem, collar, and root wounds (Nauman *et al.*, 1989; Bella *et al.*, 2003). Studies describe bacterial disease as seed-borne (Zutra, 1989; Kritzmann, 1990; Abdalla, 2000). The bacteria from infected plants can be disseminated by rain, sprinkler splash, dew, or handling. Free water on foliage surfaces and high soil nitrogen levels, resulting in more tender vegetation, promote tomato pith necrosis infection (Naumann *et al.*, 1989; Carroll *et al.*, 1992). Moreover, it has been isolated from irrigation and recirculation water.

Studies describe the bacterium as seed-borne (Zutra, 1989; Kritzmann, 1990; Abdalla, 2000). Bacterial inoculum-infected plants can be dispersed by rain, sprinkler splash, dew, or handling. Free water on foliage and high soil nitrogen promote *P. corrugata* infection (Carroll *et al.*, 1992). Moreover, it has been isolated from irrigation and recirculation water.

Management

The bacterium is a weak and opportunistic pathogen (Catara, 2007). Contaminated tomato seed lots due to *P. corrugata* have been reported in Israel (Zutra, 1989) and Egypt (Abdalla, 2000). Management of this disease starts with using disease-free seeds and healthy transplants, proper cultural production practices, i.e., field sanitation and disinfection of tools and equipment, maintaining balanced plant nutrition, and avoiding excessive nitrogen applications. Avoid planting in a previously infected area and practice crop rotation of non-host crops (Achouak *et al.*, 2000; Ivey & Miller, 2005).

RESEARCH PROSPECTS

Bacterial diseases damage vegetables, and severe infection could result in yield losses. This is partly attributable to the invasion speed as bacteria enter natural openings and wounds directly. However, only a few studies in the country deal with these diseases that affect vegetables, and appropriate management strategies are still needed. Bacterial diseases are also difficult to control compared to their counterpart pathogens, e.g., fungal diseases, where fungicides are available. However, there are practices that vegetable growers can adopt to mitigate the potential impact of the disease, minimize losses, and reduce inoculum levels in the soil. These include cultural practices using pathogen-free seeds, care in handling of the produce during harvest, sanitation, removal of weeds and alternate hosts, immediate removal of infected plant parts, and constant disease monitoring.

If disregarded and not managed well, bacterial diseases in vegetables may cause losses, significantly affecting the vegetable industry's yield, profit, and competitiveness in the Philippines. There is little information on the extent of spread, assessment of losses, local varieties with resistance to diseases, and different control methods of these common bacterial diseases of vegetables in the country. These data are essential in developing and deploying appropriate and effective management strategies for bacterial diseases. Thus, investing in research to understand the biology and epidemiology of these diseases is warranted. A search for better diagnostic tools for early and quick disease detection, exploring the use of biocontrol agents, and a more deliberated adoption of cultural practices are necessary for the holistic management of these bacterial diseases. In addition, local varieties and germplasm accessions can be screened to identify sources of resistance and develop lines with resistance and tolerance to these important bacterial diseases.

AUTHORS' CONTRIBUTION

HDA - conceptualization, data curation, writing-original draft, writing-review and editing, JJG - writing-review and editing, MAB - conceptualization, supervision, writing-review and editing.

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