AGRICULTURE ARCHIVES

OPEN ACCESS

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Review Article
ISSN: 3041-5322
Journal homepage: agriculture.researchfloor.org

One Health Perspective: A Review on Plant Pathogenic Bacteria and Human Health in Nigeria

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ABSTRACT

Plant pathogenic bacteria are conventionally studied within the narrow confines of crop science, yet a growing body of evidence indicates that the microorganisms, practices, and environments associated with plant disease management are tightly interwoven with human health outcomes. This review adopts a One Health perspective to examine the multiple pathways through which plant pathogenic bacteria and the agricultural systems built around them intersect with human wellbeing in Nigeria. Nigeria's agricultural sector, largely rural, smallholder-based, and dependent on rainfall, sustains the livelihoods of about seventy percent of the adult population and forms the foundation of the country's food security. At the same time, it faces considerable pressure from bacterial diseases affecting staple and vegetable crops, alongside unchecked agrochemical application, tainted irrigation sources, and weak post-harvest handling practices. Drawing on published Nigerian and regional literature, the review synthesises evidence on economically important phytobacterial pathogens such as Ralstonia solanacearum, Xanthomonas species, and soft-rot Pectobacterium and Erwinia species, and traces four principal pathways by which these organisms and their management intersect with human health: contamination of fresh produce and the associated burden of foodborne illness; the agro-environmental reservoir of antimicrobial resistance genes and their horizontal transfer across the soil-plant-human continuum; occupational and community exposure to pesticides applied to control bacterial and other crop diseases; and the indirect pathway through which crop losses undermine food security, nutrition, and household resilience. The review situates these findings within Nigeria's evolving One Health governance architecture, including the National One Health Strategic Plan and the multi-sectoral Technical Working Group on antimicrobial resistance, and identifies persistent gaps in intersectoral surveillance, laboratory capacity, and the integration of plant health into national One Health structures. The paper concludes that meaningfully protecting human health in Nigeria requires the explicit inclusion of plant pathology and phytosanitary systems within One Health planning, alongside strengthened food safety regulation, rational agrochemical governance, and investment in integrated surveillance that links soil, water, crop, and clinical data.

Keywords: *One Health, plant pathogenic bacteria, human health, Nigeria, antimicrobial resistance, food safety, phytosanitary systems.*

INTRODUCTION

The One Health concept holds that human, animal, plant, and environmental health are inseparable and must be addressed through coordinated, collaborative, and interdisciplinary action rather than through the isolated efforts of individual sectors. Although the concept has historically been applied most visibly to zoonotic and vector-borne diseases that move between animals and humans, there is increasing recognition that plant health belongs squarely within the One Health tent, since the plants that constitute the base of human and animal food chains are themselves subject to disease, and the microorganisms, chemicals, and practices used to manage that disease reverberate outward into human and environmental health [13].

Nigeria offers a particularly instructive setting in which to examine this expanded conception of One Health. Agriculture remains the economic mainstay of the country, absorbing a large share of the labour force and underpinning the food security of a population exceeding two hundred million people. Much of this agricultural production, however, takes place under conditions that favour the emergence and spread of bacterial plant disease: humid, warm climatic conditions across the southern and middle belt zones; continuous cropping with limited rotation; informal seed and seedling exchange that facilitates pathogen movement between farms and states; and irrigation practices that frequently rely on surface water bodies receiving untreated human and animal waste. Bacterial wilt of tomato and other solanaceous crops, bacterial blight of cowpea and cotton, and soft rot of tubers and vegetables are among the diseases that regularly erode yields and farmer income across Nigerian agro-ecological zones.

The relationship between these plant diseases and human health is not confined to the loss of food availability that follows crop failure, although that pathway alone carries serious nutritional and economic consequences.

Citation: Akpa, Abubakar Dominic, and Amodu, Umoru Simeon (2026). One Health Perspective: A Review on Plant Pathogenic Bacteria and Human Health in Nigeria. *Agriculture Archives: an International Journal.*
DOI: https://doi.org/10.51470/AGRI.2026.5.2.63

Received on: March 11, 2026
Revised on: April 12, 2026
Accepted on: May 09, 2026
Available Online: June 17, 2026

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Bacteria that cause plant disease, and the bacteria that travel with them on soil particles, irrigation water, and produce surfaces, form part of the same environmental reservoir from which many human enteric and opportunistic pathogens are drawn. The chemical inputs that farmers apply, often inappropriately, to suppress bacterial and other crop diseases expose farm families and rural communities to acute and chronic health risks. The genetic elements that confer antimicrobial resistance move readily across the boundaries that separate plant, animal, and human-associated bacteria, such that farm soils, irrigation canals, and market vegetables have all been implicated as reservoirs and conduits for resistance determinants of direct clinical relevance. This review therefore asks: what does the scientific evidence, particularly evidence generated within Nigeria, tell us about the pathways connecting plant pathogenic bacteria to human health, and what does a genuinely One Health response to these pathways require of Nigeria's research, regulatory, and health systems architecture?

It is worth noting at the outset that Nigeria is not unique in facing this constellation of challenges; comparable dynamics have been documented across Sub-Saharan Africa and in other low- and middle-income agricultural economies where informal food systems, weak agrochemical regulation, and constrained laboratory capacity coexist with high dependence on smallholder crop production. Nonetheless, the scale of Nigeria's population, the centrality of agriculture to its economy, and its position as a regional leader in West African One Health coordination efforts make it a particularly consequential case study, both for understanding the plant-human bacterial health nexus in its own right and for informing regional and continental policy responses that draw on the Nigerian experience.

The remainder of the paper is organised as follows. Section two outlines the conceptual foundations of the One Health approach and its extension to plant health. Section three reviews the major plant pathogenic bacteria of economic and public health relevance in Nigerian agriculture. Section four is the analytical core of the paper and examines four pathways linking plant pathogenic bacteria to human health: food safety and foodborne illness; antimicrobial resistance; occupational and agrochemical exposure; and food security and nutrition. Section five draws together Nigeria-specific evidence and case material. Section six reviews Nigeria's One Health governance architecture and its treatment, or neglect, of plant health. Section seven identifies structural and institutional challenges, and section eight offers recommendations before the paper concludes.

CONCEPTUAL FRAMEWORK FOR THE ONE HEALTH APPROACH

One Health is defined by the Quadripartite alliance of the Food and Agriculture Organisation of the United Nations, the World Organisation for Animal Health, the United Nations Environment Programme, and the World Health Organisation as an integrated, unifying approach that aims to sustainably balance and optimise the health of people, animals, and ecosystems, recognising that these domains are closely linked and interdependent [21]. The approach mobilises multiple sectors, disciplines, and communities at varying levels of society to work together to anticipate, prevent, detect, and respond to health threats, while simultaneously addressing the collective need for clean water, energy, air, safe and nutritious food, and action on climate change.

Historically, the practical application of One Health in low- and middle-income countries, including Nigeria, has concentrated heavily on zoonotic disease control, food safety in animal products, and antimicrobial resistance surveillance in the human and animal health sectors, with plant health frequently occupying a marginal or entirely absent position within national One Health structures [16].

A growing literature argues for a more explicit One Plant Health orientation within the broader One Health movement, on the grounds that plant disease and pest pressure directly threaten the food security, nutrition, and economic stability on which human and animal health ultimately depend, and that several economically important foodborne pathogens of humans, including *Salmonella*, *Escherichia coli*, and Listeria species, routinely contaminate fruits, vegetables, and grains at the plant-environment interface. This literature further notes that fungal plant pathogens can themselves pose direct threats to human respiratory health, and that agricultural fungicide use has been linked to the emergence of azole-resistant strains of clinically important fungi, illustrating that the boundary between phytopathology and human medicine is considerably more permeable than sectoral training and institutional arrangements typically assume.

For this review, the One Health framework is applied to plant pathogenic bacteria along three interlocking dimensions. The first is the shared microbial ecology dimension, in which soil, water, and plant surfaces function as a continuous reservoir from which both phytopathogenic and human-pathogenic bacteria, as well as the mobile genetic elements that confer antimicrobial resistance, may be drawn. The second is the shared chemical exposure dimension, in which the antibiotics, copper-based bactericides, and synthetic pesticides used to manage plant bacterial disease enter soil, water, and food systems and thereby create direct and indirect human exposure pathways. The third is the shared food and livelihood security dimension, in which the yield losses inflicted by bacterial plant disease translate into reduced dietary diversity, reduced household income, and heightened vulnerability to malnutrition and its downstream health consequences. Each of these dimensions is elaborated in the sections that follow.

This review is guided by a narrative synthesis methodology appropriate to a subject area that spans multiple, historically disconnected bodies of literature. Sources were drawn from peer-reviewed journal articles indexed in international databases, Nigerian government and multilateral policy documents, and, where peer-reviewed Nigerian data were unavailable on a specific point, closely comparable evidence from other West African and Sub-Saharan African settings. Priority was given throughout to studies conducted within Nigeria or directly addressing Nigerian institutions and policy, supplemented by global evidence where it clarifies mechanisms, such as the molecular basis of antimicrobial resistance gene transfer, that have not yet been extensively characterised within Nigerian-specific research. The review does not claim to be an exhaustive systematic review in the formal sense, but rather a structured synthesis intended to make explicit a set of connections that remain scattered across the plant pathology, public health, veterinary, environmental science, and health policy literatures.

PLANT PATHOGENIC BACTERIA OF ECONOMIC AND PUBLIC HEALTH RELEVANCE IN NIGERIAN AGRICULTURE

Bacterial plant pathogens differ substantially from the fungal and viral pathogens that dominate much of Nigerian phytopathological research in their mode of entry, dissemination, and persistence, and this has direct implications for the way they intersect with human health. Most plant pathogenic bacteria enter host tissue through wounds or natural openings such as stomata and hydathodes, multiply within intercellular spaces or vascular tissue, and are disseminated by water splash, insect vectors, contaminated tools, infected planting material, or irrigation water, all of which are pathways that also carry non-phytopathogenic bacteria of human health significance [19].

Ralstonia solanacearum and bacterial wilt

Ralstonia solanacearum, a Gram-negative, soil-borne betaproteobacterium, is widely regarded as the second most economically destructive bacterial plant pathogen worldwide and is the causal agent of bacterial wilt, a disease affecting more than two hundred and fifty plant species across fifty-four families, including tomato, potato, pepper, tobacco, groundnut, and banana. The pathogen colonises the root system through wounds and natural openings before invading the xylem vessels, where it forms biofilms that occlude water transport and produces cell wall-degrading enzymes and type III secretion system effector proteins that suppress host immune responses, culminating in the characteristic rapid wilting and vascular browning of infected plants [19]. The pathogen received its first formal characterisation in Nigeria through a tomato survey covering Ogun, Edo, Delta, Lagos, and Oyo states, where 60-80 percent of the fields examined in each state contained infected plants; the isolates responsible were classified as biovar three under Hayward's system. [2]. Bacterial wilt remains one of the principal constraints on tomato production across Nigeria's major vegetable-producing belts, and its soil-borne persistence, broad host range, and resistance to chemical control make it a paradigm case of a plant disease whose management drives farmers toward heavy reliance on broad-spectrum agrochemicals and, in some documented instances, off-label antibiotic use.

Xanthomonas species

Xanthomonas species are Gram-negative bacteria responsible for a range of economically significant diseases in Nigerian agriculture, including bacterial blight of cowpea and cotton, bacterial spot of tomato and pepper, and citrus canker. Members of this genus typically enter host tissue through stomata, hydathodes, or wounds, and, like *Ralstonia solanacearum*, deploy a type III secretion system to deliver effector proteins that manipulate host defence responses, enabling extensive colonisation of leaf and vascular tissue with visible symptoms of blight, spotting, and canker formation. Because *Xanthomonas* infections are frequently managed through repeated applications of copper-based bactericides and, in some farming systems, streptomycin-containing formulations, the disease indirectly contributes to the same chemical exposure and resistance-selection pressures associated with *Ralstonia* management.

Pectobacterium, Dickeya, and Bacterial soft rot

Soft rot *Enterobacter*iaceae, formerly classified within the genus Erwinia and now largely reassigned to Pectobacterium and Dickeya, cause extensive post-harvest losses in tubers, root crops, and succulent vegetables that are central to the Nigerian diet, including yam, potato, cassava, tomato, and leafy vegetables. These organisms produce pectinolytic enzymes that macerate plant tissue, producing the characteristic soft, watery rot that renders produce unmarketable and, in advanced stages, provides a favourable substrate for secondary colonisation by other bacteria, including strains with human pathogenic potential. Because soft rot losses occur predominantly during storage, transport, and marketing rather than in the field, they intersect directly with the informal, poorly refrigerated post-harvest and market systems through which the majority of Nigerian fresh produce passes, creating conditions in which spoiled and contaminated produce may nonetheless enter the human food chain, particularly in lower-income market segments.

Cross-Genus relevance to antimicrobial resistance

A body of molecular evidence indicates that plant pathogenic bacteria are not merely bystanders in the antimicrobial resistance landscape but active participants in its dissemination. Plasmid-borne antimicrobial resistance genes have been demonstrated to transfer from the plant pathogen Erwinia amylovora to clinically relevant human pathogens, including Corynebacterium striatum, Pseudomonas aeruginosa, and Pasteurella multocida, illustrating that the genetic barrier between phytopathogenic and human-pathogenic bacteria is porous rather than absolute [7]. This cross-genus mobility of resistance determinants is a central reason why plant pathology cannot be treated as epidemiologically isolated from human and animal health.

Bacterial blight of cowpea, cotton, and citrus canker

Beyond the vegetable-focused pathogens discussed above, *Xanthomonas* axonopodis and related pathovars cause bacterial blight in cowpea and cotton, two crops of substantial economic importance across northern and central Nigeria. Cowpea, a major source of dietary protein for millions of Nigerian households, is particularly vulnerable to bacterial blight under the humid conditions that prevail during the rainy cropping season, with infection capable of causing seed discolouration, reduced germination, and pod abortion that directly reduce both yield and the nutritional protein supply available to farming households. Citrus canker, caused by *Xanthomonas* citri, similarly threatens Nigeria's citrus-producing belts and is subject to phytosanitary quarantine measures administered by the Nigeria Agricultural Quarantine Service, reflecting the recognised risk of the pathogen's introduction and spread through infected planting material and fruit movement.

Comparative summary of pathogen characteristics

Taken together, the pathogens reviewed above share several features of direct relevance to the One Health analysis developed in this paper. All are Gram-negative bacteria capable of environmental survival outside a host plant for extended periods in soil, water, or plant debris, a trait that sustains disease pressure across cropping seasons and creates a persistent environmental reservoir rather than a transient point-source contamination event. All are managed predominantly through chemical rather than biological or genetic control in the majority of Nigerian smallholder farming systems, given the limited availability and affordability of resistant cultivars and biological control products relative to conventional agrochemicals.

A ll are linked, either directly through documented transfer of resistance genes or indirectly via shared environmental reservoirs, to organisms and genetic elements of recognised human health importance [11]. It is this convergence of environmental persistence, chemical management dependence, and microbial-genetic overlap with human pathogens that establishes the One Health relevance of bacterial plant disease in the Nigerian context, and that structures the pathway analysis presented in the following section.

PATHWAYS LINKING PLANT PATHOGENIC BACTERIA AND THEIR MANAGEMENT TO HUMAN HEALTH

The relationship between plant pathogenic bacteria and human health in Nigeria operates through several distinct but interacting pathways. This section examines four such pathways in turn: the food safety and foodborne illness pathway; the antimicrobial resistance pathway; the occupational and agrochemical exposure pathway; and the food security and nutrition pathway.

The food safety and foodborne illness pathway

Fresh fruits and vegetables grown in fields affected by bacterial plant disease, irrigated with contaminated water, or fertilised with untreated animal manure, are a well-documented vehicle for the transmission of human enteric pathogens in Nigeria. Vegetables can become contaminated with pathogenic and commensal bacteria of human and animal origin at multiple points along the value chain, from irrigation and soil contact through to harvesting, transport, market display, and vending, and the resulting contamination is compounded where produce is consumed raw or with minimal washing, as is common practice for salad vegetables, herbs, and fruit sold in Nigerian open markets [9].

Empirical studies from across Nigeria consistently document the presence of *Escherichia coli*, *Salmonella* species, *Staphylococcus aureus*, *Klebsiella* species, *Enterobacter* species, and *Citrobacter* species on fruits and vegetables sold in urban and peri-urban markets, with contamination levels frequently exceeding acceptable microbiological safety limits [15]. A survey of fruits and vegetables sold in a major market in Kaduna State, for example, identified six distinct bacterial genera on the produce examined, several of which are recognised agents of human gastrointestinal illness. Similarly, investigations of raw vegetables retailed in markets in northeastern Nigeria have documented *Salmonella* typhi and *Escherichia coli* contamination linked to poor post-harvest hygiene and the use of untreated water for washing and irrigation. In Edo State, a study of two hundred and fifty-four samples drawn from agricultural farms and open markets found extended-spectrum beta-lactamase-producing *Escherichia coli* in the majority of manure samples tested, in more than two-thirds of soil samples, and in nearly a quarter of vegetable samples, underscoring that farm-level contamination readily propagates through to the point of retail sale [9].

The public health significance of this contamination is substantial. Nigeria does not currently operate a comprehensive, functional foodborne disease surveillance system, which impedes accurate national estimation of disease burden, but available assessments suggest that foodborne illness ranks among the leading causes of morbidity within some sub-national health systems and imposes direct healthcare costs estimated in the billions of naira annually.

Populations at heightened vulnerability to the consequences of such contamination include young children, pregnant women, the elderly, and individuals living with HIV or other immunocompromising conditions, groups that are disproportionately represented among users of informal food markets and street food vendors across Nigerian cities.

The scale of Nigeria's informal fresh produce marketing system amplifies the public health significance of this contamination pathway considerably. Unlike supermarket-dominated food retail systems, where cold chain infrastructure and centralised quality control can intercept heavily contaminated batches before they reach consumers, the overwhelming majority of Nigerian fresh produce moves through open-air markets, roadside stalls, and itinerant vendors operating with minimal refrigeration, inconsistent access to clean washing water, and negligible microbiological quality control. Produce handled in this way is repeatedly exposed to additional contamination opportunities at each transaction point, from the farm gate through wholesale aggregation to final retail sale, such that initial farm-level contamination linked to bacterial plant disease and its management is frequently compounded rather than diluted by the time produce reaches the household kitchen.

The antimicrobial resistance pathway

Antimicrobial resistance has been described as a slow-moving pandemic and is recognised by Nigerian and international health authorities as one of the foremost threats to global health security, with the agricultural and environmental sectors implicated as major, and historically under-monitored, reservoirs of resistant bacteria and resistance genes [5]. Agricultural soils that receive repeated applications of manure, wastewater, or antimicrobial-containing agrochemicals accumulate antibiotic resistance genes that can persist for years after active antimicrobial use has ceased, functioning as both a reservoir and an amplifier of resistance within the wider environment. Edible crops grown in such soils have the demonstrated potential to internalise or carry resistant bacteria on their surfaces, thereby serving as a direct conduit between the agro-environmental resistome and human consumers and farmworkers [7].

A scoping review of the global literature on antimicrobial resistance in food crop value chains found that acquired resistance in both opportunistic and obligate human pathogens is disseminated across food crop systems in multiple world regions, with the highest risk of exposure associated with crops that are consumed raw or with minimal processing, precisely the consumption pattern that characterises much of Nigerian vegetable and salad intake [7]. The review further highlighted that plasmid-borne resistance determinants can move between plant pathogenic bacteria and clinically important human pathogens, providing direct molecular evidence for the cross-sectoral mobility of resistance genes rather than a merely theoretical concern [7].

Nigerian-generated evidence corroborates these global patterns. Multidrug-resistant *Escherichia coli* strains carrying class one integrons, genetic elements strongly associated with the acquisition and dissemination of antimicrobial resistance, have been isolated from surface waters and vegetables in Enugu State, implicating irrigation water quality as a key determinant of resistance transfer into the food chain. In Edo State, ESBL-producing *Escherichia coli* isolated from farm soil, manure, irrigation water, and market vegetables displayed resistance profiles consistent with agricultural antimicrobial use,

while parallel surveillance of surface water sources in the same state identified a wide array of tetracycline and quinolone resistance genes, with prevalence patterns linked to the proximity of livestock, human settlement, and agricultural activity to the sampled water bodies [9]. A national mixed-methods prioritisation exercise involving human and animal health professionals across Nigeria identified *Salmonella* species and *Escherichia coli* as the top-ranked priority pathogens for antimicrobial resistance intervention, with unsanitary agricultural and abattoir practices and inadequate infection prevention and control identified as principal drivers requiring cross-sectoral attention [5].

A systematic review and meta-analysis of ESKAPE pathogens, comprising Enterococcus faecium, *Staphylococcus aureus*, *Klebsiella* pneumoniae, *Acinetobacter baumannii, Pseudomonas aeruginosa*, and *Enterobacter* species, across Africa found that West Africa recorded the highest pooled prevalence estimates of these pathogens on the continent, with substantial isolation from environmental, food, and animal-derived samples in addition to clinical specimens, reinforcing the case for surveillance systems that span the human-animal-environment interface rather than remaining confined to hospital laboratories [10]. Taken together, this evidence indicates that Nigerian agricultural soils, irrigation water, and market produce, all of which are directly shaped by the presence and management of bacterial plant disease, function as an active and under-monitored component of the national and regional antimicrobial resistance landscape.

The clinical stakes of this environmental resistance reservoir are considerable. ESKAPE pathogens and other priority resistant organisms detected in Nigerian agricultural and market samples are the same organisms responsible for prolonged hospital stays, increased treatment costs, and elevated mortality among hospitalised patients across Nigerian tertiary health facilities. When resistant strains or their resistance genes move from farm soil or irrigation water into the human gut microbiome through consumption of contaminated produce, they do not need to cause acute illness to be of clinical concern; their mere acquisition and persistence within the human microbiome creates a reservoir from which resistance determinants can subsequently transfer to genuinely pathogenic organisms during future infections, complicating treatment choices in ways that may only become apparent months or years after the initial exposure event. This latency, together with the practical difficulty of tracing any individual patient's resistant infection back to a specific agricultural exposure, is a central reason why the agricultural dimension of antimicrobial resistance has historically received less policy attention in Nigeria than the more visible clinical and veterinary dimensions of the problem, despite the substantial molecular and epidemiological evidence reviewed above.

The occupational and agrochemical exposure pathway

The management of bacterial and other plant diseases in Nigeria relies overwhelmingly on chemical control, including copper-based bactericides, broad-spectrum fungicides frequently applied against mixed disease complexes, and, in some documented farming communities, off-label antibiotic formulations intended for veterinary or human use. This reliance on chemical inputs occurs within a regulatory and educational environment characterised by weak enforcement, limited farmer training, and widespread use of highly hazardous pesticide formulations that have been banned or restricted in many other jurisdictions.

Survey-based studies conducted across multiple Nigerian states document a consistent pattern of unsafe pesticide handling practices. In Kano metropolis, the overwhelming majority of surveyed farmers reported using pesticides without adequate protective equipment, purchasing chemicals from open markets and informal shops rather than certified dealers, and disposing of pesticide containers without adequate decontamination, with containers frequently repurposed for domestic use. In Gombe State, approximately one-third of the farmers surveyed indicated that they applied pesticides without personal protective equipment, while fewer than forty percent had received any formal training in safe pesticide handling [12]. Farmers in northern Nigeria commonly reported acute symptoms following pesticide application, including headache, dizziness, skin irritation, eye irritation, coughing, and nausea, symptom patterns consistent with organophosphate and other pesticide toxicity. Haematological and immunological investigations of Nigerian farmworkers occupationally exposed to organophosphate pesticides have documented significantly reduced acetylcholinesterase activity, altered white blood cell counts, and disrupted immunoglobulin profiles relative to unexposed controls, providing direct clinical evidence of the physiological toll of unsafe pesticide use.

The persistence of banned agrochemicals compounds these risks. Investigative and scientific reporting has documented the continued presence of organochlorine pesticides such as lindane, banned in Nigeria for well over a decade, in soils and farm produce in parts of the country, reflecting weak market surveillance and continued informal availability of restricted products. A soil assessment across commercial farms in southern Nigeria similarly found that fewer than two-fifths of surveyed farmers had received training on safe pesticide application, and that organochlorine pesticide residues, while generally within minimum risk levels, exceeded thresholds in specific localities, indicating localised but real human health risk from soil and, by extension, crop contamination.

Beyond acute occupational toxicity, farmers' own health perceptions provide indirect but consistent corroborative evidence of these risks. Studies in southeastern Nigeria have found that farmers frequently attribute mood disturbances, anxiety, and other neurological symptoms to agrochemical exposure, and that low literacy and poor comprehension of pesticide labelling are significant contributors to unsafe handling practices [17]. Because the diseases that these agrochemicals are deployed against include bacterial wilt, bacterial blight, and bacterial soft rot among others, the occupational and community health burden associated with pesticide use in Nigeria cannot be fully understood without reference to the bacterial, fungal, and viral disease pressures that drive farmers toward heavy and often indiscriminate chemical use.

The food security, nutrition, and livelihood pathway

Yield losses of up to ninety percent have been linked to bacterial wilt alone in severely affected solanaceous crop fields, while comparable reductions caused by bacterial blight, bacterial spot, and soft rot are routinely documented across Nigeria's vegetable and tuber production systems [4]. Because these crops, particularly tomato, pepper, and yam, are central to Nigerian dietary patterns and household income generation for smallholder farmers, disease-driven yield losses translate directly into reduced dietary diversity, reduced household purchasing power, and heightened food insecurity, particularly

in rural farming communities that depend on the same crops for both subsistence and cash income.

The nutritional consequences of this pathway are especially significant for children and pregnant women, populations for whom micronutrient-dense vegetables constitute an important dietary source of vitamins and minerals not readily available from staple cereal and tuber consumption alone. Reduced availability and affordability of vegetables associated with bacterial disease outbreaks can therefore compound existing patterns of micronutrient deficiency and undernutrition in Nigerian households, particularly during periods of seasonal disease pressure that coincide with the pre-harvest hunger gap common in many farming communities. This pathway, although less immediately visible than acute foodborne illness or occupational pesticide poisoning, represents a chronic and cumulative dimension of the relationship between plant bacterial disease and human health that warrants explicit attention within Nigerian food security and nutrition policy.

The environmental and ecosystem health pathway

A fifth, more diffuse pathway operates through the effects of bacterial plant disease management on the broader agro-ecosystem services on which human health ultimately depends. Repeated and often excessive application of copper-based bactericides to control diseases such as bacterial spot and bacterial blight leads to progressive copper accumulation in agricultural soils, a phenomenon documented in intensively managed vegetable production systems worldwide and increasingly of concern in Nigerian horticultural belts where copper formulations are applied with limited attention to cumulative loading or soil monitoring. Elevated soil copper concentrations are toxic to beneficial soil microbiota, earthworms, and other components of the soil food web that underpin nutrient cycling, water infiltration, and long-term soil fertility, creating a slow-onset degradation of the agro-ecosystem's capacity to sustain future food production. Similarly, broad-spectrum agrochemical use directed at bacterial and mixed disease complexes has documented non-target effects on pollinator populations and aquatic invertebrate communities in receiving water bodies, effects that carry their own downstream implications for crop pollination services and fisheries-based protein sources relevant to rural Nigerian diets. Although this pathway operates over a longer time horizon than the acute contamination and occupational exposure pathways discussed above, its cumulative erosion of agro-ecosystem resilience represents a further dimension through which the management of plant pathogenic bacteria intersects with the long-term sustainability of human food and health security in Nigeria.

Climate change as a cross-cutting amplifier

Climate variability and change interact with each of the pathways described above in ways that are likely to intensify rather than diminish the human health relevance of plant pathogenic bacteria in Nigeria over the coming decades. Rising temperatures and shifting rainfall patterns are projected to expand the geographic range and seasonal window of favourable conditions for bacterial wilt, bacterial blight, and soft rot pathogens, particularly in the humid tropical and sub-humid zones that already bear the heaviest disease burden. Increased frequency of intense rainfall events elevates the risk of flooding-associated contamination of farmland with sewage and animal waste, a documented driver of both bacterial plant disease outbreaks and food safety contamination events.

At the same time, climate-driven pressure to intensify or expand agricultural production in response to reduced yields may increase farmer reliance on agrochemical inputs, thereby amplifying the occupational and environmental exposure pathways discussed above. These interactions underscore that the plant-human bacterial health nexus examined in this review is not a static phenomenon but one whose scale and urgency are likely to grow under prevailing climate trajectories, reinforcing the case for its explicit incorporation into Nigeria's climate adaptation and health security planning.

SYNTHESIS OF NIGERIA-SPECIFIC EVIDENCE AND CASE MATERIAL

The Nigerian evidence base reviewed in the preceding sections converges on several consistent findings. First, bacterial wilt caused by *Ralstonia solanacearum* has been documented across Nigeria's major tomato-producing states since at least the mid-1990s, with infection rates in some surveyed fields reaching eighty percent, indicating that the pathogen is endemic rather than sporadic across southwestern Nigerian vegetable production zones [2]. Second, the same agricultural environments implicated in bacterial plant disease, namely farm soil, irrigation water, and animal manure used as fertiliser, are independently and repeatedly identified in Nigerian microbiological surveillance studies as reservoirs of antimicrobial-resistant *Escherichia coli* and other *Enterobacter*iaceae, with resistance genes detected in the majority of tested manure and soil samples in at least one Edo State study [9].

Third, market surveillance studies from Kaduna, Yobe, and other Nigerian states consistently identify bacterial contamination of fresh produce at levels that raise public health concern, with the specific organisms detected, including *Escherichia coli*, *Salmonella* species, and *Staphylococcus aureus*, overlapping substantially with organisms of both plant-associated and directly zoonotic or anthroponotic origin. Fourth, occupational health surveys of Nigerian farmers across multiple geopolitical zones, from Kano in the north to Bayelsa and Rivers in the south, document a remarkably consistent pattern of inadequate protective equipment use, informal and unregulated pesticide procurement, and self-reported acute health symptoms following pesticide application, regardless of the specific crop or disease targeted.

Fifth, at the national policy level, expert prioritisation exercises conducted under a One Health framework have identified *Salmonella* and *Escherichia coli*, both organisms with well-documented plant-associated environmental reservoirs, as the top public health priority pathogens for antimicrobial resistance intervention in Nigeria, while simultaneously noting that environmental sector stakeholders, within which plant health and agricultural extension would logically sit, remain the least engaged of the three One Health sectors in national antimicrobial resistance surveillance and response efforts [5]. This gap is significant because it suggests that the very pathogens identified as top national priorities have environmental and agricultural transmission pathways that are not yet systematically monitored or addressed.

A closer reading of the tomato bacterial wilt case illustrates how these separate strands of evidence converge in practice on a single Nigerian farming system. Tomato remains one of Nigeria's most economically important vegetable crops and one of the most heavily chemically managed, given the combined pressure of bacterial wilt, bacterial spot, early and late blight, and a range of insect pests that transmit additional pathogens.

Farmers confronting bacterial wilt outbreaks, a disease with no effective curative chemical treatment once vascular colonisation has occurred, frequently respond by intensifying overall spray regimes in the hope of suppressing secondary infections and insect vectors, by shortening pre-harvest intervals to salvage marketable fruit ahead of anticipated crop collapse, and by drawing irrigation water from the nearest available surface source regardless of its contamination status. Each of these farmer-level responses, individually rational given the absence of curative options and the economic pressure to recoup input costs, plausibly intensifies one or more of the pathways examined in this review: agrochemical residue exposure for farmworkers and, potentially, consumers; reduced pre-harvest intervals that increase pesticide residue carryover onto marketed fruit; and irrigation-borne microbial contamination that has been independently documented in Nigerian surface water studies. The tomato case therefore functions as a useful lens through which the four pathways described in section four can be seen operating simultaneously within a single, economically vital Nigerian cropping system, rather than as separable, independent phenomena.

The poultry-vegetable market interface offers a further illustrative example of pathway convergence. Nigerian open markets characteristically co-locate fresh vegetable and fruit vendors with poultry and other meat retailers, often sharing drainage, water sources, and waste disposal infrastructure. Surveillance of poultry meat sold through processing plants and retail markets in Ibadan has documented substantial *Salmonella* and *Escherichia coli* contamination, with resistance patterns of direct antimicrobial stewardship concern [3]. Given the shared physical infrastructure of Nigerian wet markets, the potential for cross-contamination between animal-source and plant-source food items, and the resulting complexity of tracing any given case of foodborne illness back to its precise point of origin, is considerable, further reinforcing the case for integrated rather than sector-siloed food safety surveillance.

ONE HEALTH GOVERNANCE AND POLICY RESPONSE IN NIGERIA

Nigeria has made notable institutional progress in operationalising the One Health approach over the past decade. The Nigeria Centre for Disease Control and Prevention, established by an Act of the National Assembly signed into law in November 2018, serves as the country's national public health institute and has been designated the secretariat for national One Health coordination functions. In December 2019, the Federal Ministries of Health, Agriculture and Rural Development, and Environment jointly launched Nigeria's first National One Health Strategic Plan, covering the period 2019 to 2023, with the explicit objective of strengthening multi-sectoral collaboration for the prevention, detection, and response to health threats occurring at the human-animal-environment interface [14].

This strategic architecture has been complemented by the establishment of a National One Health Steering Committee and a National One Health Technical Committee, bringing together representatives of human health, veterinary, agricultural, and environmental agencies alongside international partners including the Food and Agriculture Organisation, the World Organisation for Animal Health, the United Nations Environment Programme, and the World Health Organisation under the Quadripartite alliance framework [18].

A dedicated Technical Working Group on antimicrobial resistance, operating under the Antimicrobial Resistance Coordinating Committee led by the Nigeria Centre for Disease Control, has supported the establishment of antimicrobial resistance surveillance capacity in laboratories across the human and animal health sectors, and Nigeria has developed a National Action Plan on Antimicrobial Resistance intended to guide cross-sectoral response.

Despite these advances, published assessments of Nigeria's One Health implementation identify persistent structural weaknesses. Monitoring and enforcement of the 2019 to 2023 strategic plan have been described as inadequate, and professional silos rooted in Nigeria's medical, veterinary, and agricultural training systems continue to discourage the multidisciplinary collaboration that One Health requires, compounded by bureaucratic friction between ministries and limited practical support for professionals seeking to work across sectoral boundaries. A regional assessment of the Economic Community of West African States' One Health Coordination Mechanism, in which Nigeria played a founding role through hosting the 2017 Abuja consultative meeting, similarly found that political commitment, institutional structure, and financial resourcing for cross-sectoral One Health coordination remained inconsistent across the West African region during the mechanism's initial implementation period.

Most significantly for the purposes of this review, the environmental and agricultural dimensions of Nigeria's One Health architecture remain comparatively underdeveloped relative to the human and animal health sectors, and plant health specifically does not appear as an explicitly named pillar within the documented structure of the national strategic plan, the Steering Committee, or the antimicrobial resistance Technical Working Group. Given the evidence reviewed in section four demonstrating that agricultural soils, irrigation water, and crop produce function as active reservoirs and transmission pathways for organisms and resistance genes of direct human health significance, this institutional gap represents a meaningful blind spot in Nigeria's otherwise commendable progress toward operational One Health governance.

Several additional Nigerian institutions carry mandates directly relevant to the pathways examined in this review, even though their integration with the formal One Health coordination architecture remains limited. The National Agricultural Quarantine Service is responsible for phytosanitary inspection and certification of plant and plant product movement across Nigeria's borders, a function directly relevant to preventing the introduction and spread of exotic bacterial pathogens such as additional *Xanthomonas* and *Ralstonia* strains not yet established within the country. The National Agency for Food and Drug Administration and Control regulates the registration, importation, and, in principle, market surveillance of both agrochemicals and food products, placing it at the intersection of the occupational exposure and food safety pathways described above. The Standards Organisation of Nigeria maintains food safety and agricultural input standards, while the National Environmental Standards and Regulations Enforcement Agency holds a mandate over environmental contamination that intersects with agricultural runoff and soil quality. The explicit, functional integration of these agencies, alongside the university and research institute system that trains Nigeria's plant pathologists, veterinarians, and physicians, into a shared One Health data and coordination

architecture remains an unrealised objective rather than an accomplished institutional reality.

CHALLENGES TO INTEGRATING PLANT PATHOGENIC BACTERIA INTO NIGERIA'S ONE HEALTH RESPONSE

Institutional and disciplinary fragmentation

Nigerian agricultural extension, plant pathology research, and phytosanitary regulation are institutionally housed within the Federal Ministry of Agriculture and its associated research institutes and universities, structures that have historically operated with limited routine interaction with the human health surveillance systems coordinated by the Nigeria Centre for Disease Control or the veterinary systems coordinated through the Federal Ministry of Agriculture's animal health department. This fragmentation means that data on crop bacterial disease outbreaks, agrochemical use patterns, and farm-level microbiological contamination rarely reach human health surveillance systems in a timely or systematic way, and conversely that human health data on foodborne illness or pesticide poisoning are seldom fed back into agricultural extension and phytosanitary decision-making.

This fragmentation is reinforced by Nigeria's federal system of governance, in which agricultural extension and much of food market regulation fall substantially within state and local government jurisdiction, while public health emergency coordination and antimicrobial resistance surveillance are led at the federal level through the Nigeria Centre for Disease Control. The resulting need to coordinate across thirty-six states and the Federal Capital Territory, each with varying administrative capacity and political priority attached to One Health coordination, adds a further layer of complexity beyond the sectoral fragmentation already discussed, and helps explain why national strategic plans, however well designed, have historically struggled to achieve consistent sub-national implementation.

Weak food safety and agrochemical regulation

Nigeria's food safety regulatory architecture, anchored in the National Agency for Food and Drug Administration and Control, faces well-documented resource, staffing, and enforcement constraints that limit routine microbiological and chemical residue surveillance of fresh produce moving through the country's predominantly informal market systems [16]. Similarly, although Nigeria maintains a list of banned and restricted pesticide products, enforcement at the point of sale remains weak, permitting continued informal availability of hazardous and banned formulations, as documented in investigative reporting on persistent organochlorine pesticide use in Nigerian farming communities.

Compounding these enforcement gaps is the fragmented and, in places, overlapping nature of Nigeria's food and agrochemical regulatory mandates, which are distributed across the National Agency for Food and Drug Administration and Control, the Standards Organisation of Nigeria, the National Environmental Standards and Regulations Enforcement Agency, and state-level ministries of agriculture and environment, without a single, clearly designated lead agency for agricultural chemical residues in fresh produce specifically. This distributed mandate structure, while not unique to Nigeria among developing food regulatory systems, creates ambiguity regarding accountability for the specific pathway examined in this review and complicates the kind of streamlined, rapid regulatory response that effective food safety governance requires.

Limited laboratory and surveillance capacity

Nigeria does not currently operate a comprehensive, functional national foodborne disease surveillance system capable of systematically linking clinical cases of gastrointestinal illness to specific food sources, agricultural origins, or microbiological causes. Antimicrobial resistance surveillance capacity, while expanding under the Technical Working Group's support, remains concentrated in a limited number of human and animal health laboratories, with negligible dedicated capacity for routine surveillance of resistance genes or resistant organisms in agricultural soil, irrigation water, or crop produce, despite the substantial body of research evidence, reviewed in section four, demonstrating the relevance of these environmental compartments to human antimicrobial resistance risk.

Even where laboratory infrastructure exists, sustainability of testing capacity is frequently constrained by inconsistent funding for reagents, equipment maintenance, and quality assurance participation, issues that have been documented across Nigerian public health and veterinary laboratories more broadly and that apply with equal or greater force to the comparatively under-resourced environmental and agricultural testing facilities relevant to the pathways examined in this review [6]. Donor-supported laboratory strengthening initiatives, while valuable, have in some instances struggled to achieve long-term sustainability once initial project funding concludes, underscoring the importance of embedding surveillance capacity within recurrent domestic budget allocations rather than relying primarily on time-limited external support.

Farmer knowledge, literacy, and extension gaps

The occupational health evidence reviewed above consistently implicates limited farmer literacy, inadequate access to safety training, and weak agricultural extension outreach as proximate drivers of unsafe pesticide handling practices across Nigerian farming communities. Extension services that do reach farmers frequently emphasise yield-maximising disease control recommendations without commensurate attention to safe handling, protective equipment use, or the human health implications of agrochemical misuse, reflecting the same disciplinary fragmentation between agricultural and public health training identified above.

Resource constraints and competing health priorities

Nigeria's public health system continues to contend with a substantial burden of established infectious disease priorities, including malaria, tuberculosis, HIV, and recurrent outbreaks of Lassa fever, cholera, and other epidemic-prone diseases, which understandably absorb the majority of available domestic and donor health financing. Within this constrained resourcing environment, the comparatively diffuse and less immediately visible health risks associated with plant pathogenic bacteria and agricultural chemical exposure struggle to attract the sustained policy attention and financing commensurate with the scale of evidence reviewed in this paper.

Research and evidence gaps

This review also surfaces several specific gaps in the Nigerian evidence base that constrain both scientific understanding and policy response. First, molecular characterisation of antimicrobial resistance gene transfer specifically between Nigerian plant pathogenic bacteria and clinically relevant human pathogens remains limited, with much of the

mechanistic evidence for such transfer, including the documented case of Erwinia amylovora, drawn from research conducted outside Africa. Second, quantitative estimates of the foodborne disease burden attributable specifically to produce contaminated via plant-disease-affected agricultural systems, as distinct from foodborne illness of animal origin, are largely absent from the Nigerian public health literature, limiting the ability of policymakers to prioritise this pathway relative to competing health investments. Third, longitudinal data tracking pesticide residue trends, agrochemical use intensity, and associated health outcomes across Nigerian farming communities over time remain sparse, with most available studies offering single time-point, geographically limited snapshots. Fourth, the economic impact of bacterial plant diseases on Nigeria's food security and nutrition outcomes has yet to fully quantified in a way that permits direct comparison with the burdens linked to antimicrobial resistance and food safety pathways, thereby hindering efforts to prioritise investment across these related, yet distinct issues [1]. Addressing these evidence gaps should be considered a parallel priority alongside the institutional and policy recommendations that follow.

Filling these gaps will require sustained collaboration between Nigerian universities, national research institutes such as the National Horticultural Research Institute and the National Institute for Pharmaceutical Research and Development, and international research partners, supported by dedicated funding streams that explicitly recognise the interdisciplinary, cross-sectoral nature of the plant-human bacterial health nexus rather than channelling resources exclusively through single-discipline agricultural or medical research grant mechanisms.

RECOMMENDATIONS

Addressing the intersections between plant pathogenic bacteria and human health identified in this review requires deliberate, cross-sectoral action along several fronts as outlined below.

Institutionalising plant health within one health governance

Plant health should be explicitly and formally incorporated as a named pillar within Nigeria's National One Health Strategic Plan and its associated coordination structures, with the Federal Ministry of Agriculture's plant health and phytosanitary units, together with the National Agricultural Quarantine Service, represented alongside animal and environmental health agencies in the National One Health Steering Committee and its Technical Working Groups. This institutional recognition should be accompanied by concrete terms of reference specifying data-sharing obligations, joint outbreak investigation protocols for events with plausible plant-associated origins, such as multi-state vegetable-linked gastrointestinal illness clusters, and dedicated budget lines within the strategic plan's successor document covering the period beyond 2023.

Extending environmental antimicrobial resistance surveillance

Nigeria's antimicrobial resistance surveillance architecture should be extended to include routine, geographically representative sampling of agricultural soil, irrigation water, and market produce, integrated with existing human and animal health laboratory networks under the Technical Working Group on antimicrobial resistance.

Given the resource constraints documented above, this expansion could initially proceed through sentinel site surveillance concentrated in the major vegetable-producing belts of Kano, Kaduna, Oyo, Ogun, and Edo states, generating a foundational environmental resistome dataset that can subsequently inform decisions about wider national rollout.

Strengthening food safety regulation and market surveillance

The National Agency for Food and Drug Administration and Control and relevant state ministries should strengthen routine microbiological and agrochemical residue testing of fresh produce at major urban markets, with particular attention to vegetables typically consumed raw, and should establish feedback mechanisms linking market surveillance findings to agricultural extension and phytosanitary interventions at the farm level. Public reporting of aggregated, anonymised market surveillance results, similar to practices in other food safety jurisdictions, could additionally support consumer awareness without stigmatising individual vendors who are themselves operating within a weakly regulated supply chain.

Reforming agrochemical regulation and farmer practice

Pesticide regulation and enforcement should be strengthened at points of import, formulation, and retail sale, with particular attention to closing the informal market channels through which banned and highly hazardous formulations continue to reach Nigerian farmers, as documented in recent investigative and scientific reporting on organochlorine persistence. This regulatory effort should be complemented by expanded farmer training in integrated pest and disease management approaches, including resistant variety adoption, crop rotation, and biological control options, that reduce overall reliance on broad-spectrum chemical control of bacterial and other plant diseases.

Embedding occupational health within agricultural extension

Agricultural extension curricula and farmer training programmes should integrate basic occupational health messaging, including protective equipment use, safe pesticide storage and disposal, correct pre-harvest interval observance, and recognition of acute pesticide toxicity symptoms, alongside existing technical content on crop disease identification and management. Given the literacy constraints documented in the southeastern Nigeria farmer perception studies reviewed above, such messaging should be delivered through pictorial, radio, and demonstration-based formats rather than relying solely on printed label instructions.

Building interdisciplinary human capital

Nigerian universities and research institutes offering training in plant pathology, veterinary medicine, and human medicine should expand interdisciplinary One Health curricula and joint research opportunities, building on existing institutional commitments such as those articulated by faculty at Ahmadu Bello University, in order to cultivate a cadre of professionals equipped to work across the plant-animal-human health interface. Joint postgraduate research grants and cross-listed courses spanning agricultural and medical faculties would provide a practical, low-cost mechanism for beginning to dissolve the disciplinary silos identified as a central barrier in section seven.

Investing in integrated surveillance infrastructure

Finally, investment in a functional, integrated foodborne disease surveillance system, capable of linking clinical, laboratory, and agricultural source data, should be prioritised as a foundational component of Nigeria's broader public health surveillance modernisation efforts. Such a system would allow the country to move from the current reliance on scattered, geographically limited academic surveys, of the kind synthesised in this review, toward a routine, nationally representative evidence base capable of supporting timely outbreak response and longer-term policy evaluation.

None of these seven recommendations requires Nigeria to construct entirely new institutions from first principles; rather, each builds incrementally on existing structures, including the National One Health Strategic Plan, the Technical Working Group on antimicrobial resistance, the National Agricultural Quarantine Service, and the university system's growing embrace of One Health curricula, extending their current mandates to explicitly capture the plant-human bacterial health pathways documented in this review. Sequencing and prioritisation among these recommendations will necessarily depend on available financing and political will, but the institutional recognition of plant health within One Health governance structures, discussed first above, represents a foundational and comparatively low-cost first step capable of catalysing progress across the remaining six areas.

CONCLUSION

Plant pathogenic bacteria are frequently treated, both institutionally and in the research literature, as a matter internal to agricultural science, of concern chiefly for their impact on crop yield and farmer income. This review has argued, on the basis of Nigerian and regional evidence, that such a framing is incomplete. The bacteria responsible for bacterial wilt, bacterial blight, and bacterial soft rot in Nigerian crops overlap with organisms of direct clinical relevance to humans, sharing common environmental reservoirs, similar modes of spread, and, in certain documented instances, genetic determinants of resistance [20].The chemical inputs deployed to manage these plant diseases carry demonstrated occupational and community health costs for Nigerian farming populations. And the yield losses these diseases inflict carry nutritional and food security consequences that constitute a slower but no less real dimension of human health harm. A genuinely comprehensive One Health response in Nigeria, one capable of matching the ambition articulated in the country's National One Health Strategic Plan, must therefore extend its institutional reach to explicitly encompass plant health, phytosanitary regulation, and agricultural chemical governance alongside its existing focus on zoonotic disease and animal-sourced antimicrobial resistance. The evidence reviewed here suggests that Nigeria possesses the institutional foundations, technical expertise, and international partnerships necessary to make this extension, and that doing so would close a significant and currently under-addressed gap in the country's protection of human health at the human-animal-plant-environment interface. The stakes of closing this gap extend well beyond the technical concerns of any single agency or discipline. Nigeria's continuing burden of antimicrobial resistance, foodborne illness, occupational pesticide toxicity, and nutritional vulnerability are each shaped, in part, by decisions made and pressures experienced on millions of smallholder farms confronting bacterial and other crop diseases every growing season.

Recognising plant pathogenic bacteria and their management as legitimate, evidence-based One Health concerns, rather than as matters external to human health policy, is therefore not merely a conceptual refinement but a practical necessity for a country whose health security remains inseparable from the health of its soils, its water, and the crops that sustain the great majority of its population. Future research, policy design, and donor investment in Nigerian One Health programming would benefit from treating this plant-human bacterial nexus as a core, rather than peripheral, component of the national One Health agenda.

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