Journal of Agriculture and Rural Development in the Tropics and Subtropics
Vol. 127 (2026) 143–155

https://doi.org/10.17170/kobra-2026032612024 ISSN: 2363-6033 (online); 1612-9830 (print) – website: www.jarts.info

# Potato disease risks and management strategies in sub-Saharan Africa: A systematic review and meta-analysis

Willard Mbewe [a,*], Andrew Mtonga [b], Abel Sefasi [c], Maryrose Nyakio [d], Obed Mwenye [e]

[a]Department of Biological Sciences, Malawi University of Science and Technology, Thyolo, Malawi
[b]Department of Agricultural Research Services, Chitedze Agricultural Research Station, Lilongwe, Malawi
[c]Hortuculture Department, Lilongwe University of Agriculture and Natural Resources, Lilongwe, Malawi
[d]Biological Physical and Health Sciences Department, School of Science, Agriculture and Environmental Studies, Rongo University, Kenya
[e]International Potato Centre, Malawi

**Abstract**

Potato (*Solanum tuberosum* L.) is a vital food security crop in sub-Saharan Africa (SSA), yet its productivity is significantly hindered by plant diseases and inadequate plant health systems. Despite increased potato production in regions such as Kenya, Ethiopia, and Malawi, diseases like late blight, bacterial wilt, viral complexes, and soft rot lead to substantial yield losses, jeopardizing sustainability. This study synthesises disease risks and management strategies using a systematic review and quantitative analysis framework. A systematic literature review compiled empirical data on disease prevalence and management across SSA, integrating country-level production statistics with a vulnerability index to evaluate production scale and disease risk connections. A disease risk assessment matrix prioritised pathogen based on prevalence and economic impact, identifying late blight and bacterial wilt as critical threats. The meta-analysis showed that disease management interventions could enhance yields by an average of 28 % and reduce disease incidence by approximately 42 %. Cost-effectiveness analysis highlighted certified seed systems, resistant varieties, and chemical controls as the most effective management strategies, although economic and institutional barriers limit adoption. Additionally, a sustainability gap was noted, with highly sustainable technologies experiencing low adoption compared to conventional methods. The findings underscore the necessity of strengthening plant health systems, enhancing seed system capacity, and promoting integrated disease management methods to boost potato productivity in SSA. A strategic roadmap is proposed, focusing on implementing certified seed systems, disease surveillance networks, farmer training, and climate-smart agricultural practices. Strengthening these areas is crucial for improving resilience and ensuring sustainable potato production, thereby enhancing the crop's role in food security in sub-Saharan Africa.

*Keywords:* bacterial wilt, food security, integrated disease management, late blight, potato diseases, seed systems

## 1 Introduction

Potato *(Solanum tuberosum* L.) is one of the important food crops globally and plays a critical role in improving food security, nutrition, and income generation in many developing regions. The crop provides a highly productive source of calories, carbohydrates, vitamins, and minerals for millions of people (Devaux *et al.*, 2021; Mickiewicz *et al.*, 2022). Its relatively short growth cycle, high yield potential, and adaptability to diverse agro-ecological conditions make it particularly valuable for smallholder farming systems in sub-Saharan Africa (SSA), where population growth and increasing food demand require sustainable intensification of agricultural production (De Vries *et al.*, 2016; Muthoni & Shimelis, 2022; Tiwari *et al.*, 2022).

Over the past two decades, potato production in SSA has expanded rapidly due to increasing urban demand, changing dietary preferences, and growing recognition of potato as a climate-resilient food crop (Devaux *et al.*, 2021). Several

* Corresponding author – wmbewe@must.ac.mw

Published online: 24 September 2026 – Received: 28 March 2026 – Accepted: 9 July 2026

countries in eastern and central Africa, including Kenya, Ethiopia, Uganda, and Rwanda, have experienced substantial increases in potato production and consumption (Devaux *et al.*, 2021; Muthoni & Shimelis, 2022). Despite this growth, potato productivity in SSA remains considerably lower than global averages. One of the most significant constraints to potato productivity in the region is the widespread occurrence of plant diseases that cause substantial yield losses and increase production risks for farmers (Chakrabarti *et al.*, 2022; Wenninger & Rashed, 2024).

Plant diseases are widely recognised as major drivers of global crop losses. Recent estimates suggest that pests and pathogens are responsible for yield losses of approximately 20–40 % in major food crops worldwide, posing significant threats to global food security (Ojiambo, 2025; Wenninger & Rashed, 2024). In potato production systems, diseases such as late blight (Phytophthora infestans), bacterial wilt (Ralstonia solanacearum), viral complexes, and soft rot pathogens frequently cause severe production losses, particularly in smallholder systems where access to disease management technologies is limited (Ojiambo, 2025; Khalid *et al.*, 2026; Wenninger & Rashed, 2024). Late blight alone has been described as one of the most devastating diseases in potato production due to its rapid epidemic development and capacity to evolve resistance to fungicides and host resistance genes (Laizer & Mduma, 2025; Ojiambo, 2025; Phungula *et al.*, 2025).

In SSA, the impacts of potato diseases are exacerbated by systemic weaknesses in plant health systems, including limited availability of certified seed, weak disease surveillance infrastructure, and inadequate access to extension services and improved technologies (Devaux *et al.*, 2021). The widespread use of farm-saved seed and informal seed systems contributes to the accumulation and spread of seed-borne pathogens across production cycles, leading to progressive yield decline and increased vulnerability to disease outbreaks (Kiige *et al.*, 2026). Additionally, climate variability and changing environmental conditions may further influence disease dynamics and pathogen distribution, potentially increasing disease pressure in many potato-growing regions (Khalid *et al.*, 2026).

Although various disease management strategies have been developed, including resistant varieties, improved seed systems, biological control agents, and integrated pest management approaches, the adoption of these technologies remains uneven across the region (Devaux *et al.*, 2021; Munyaneza & Bizimungu, 2022). Smallholder farmers often rely heavily on chemical fungicides or low-cost cultural practices due to limited access to improved seed systems and diagnostic services. This creates a significant gap between available disease management innovations and their practical implementation in smallholder farming systems.

Addressing this challenge requires a comprehensive understanding of the regional disease landscape, including the relative importance of different pathogens, the effectiveness of available management strategies, and the institutional and technological barriers that limit adoption. Previous studies have examined individual diseases or management technologies in specific production contexts, but few studies have attempted to synthesize these insights across multiple countries and production systems within SSA.

The present study therefore provides an integrated assessment of potato disease risks and management strategies in SSA. Using a systematic review and quantitative synthesis approach, the study examines the relationship between national production scale and disease vulnerability, prioritizes major potato diseases based on epidemiological risk, evaluates the effectiveness of disease management interventions through meta-analysis, and assesses the cost-effectiveness and sustainability of different management strategies. In addition, the study evaluates technology adoption patterns and proposes a strategic implementation roadmap for strengthening potato disease management systems in SSA. By integrating epidemiological analysis with technological and institutional perspectives, this study aims to provide evidence-based insights that can support the development of more resilient and sustainable potato production systems across SSA. The findings are intended to inform research priorities, agricultural policy development, and the design of interventions aimed at improving disease management and enhancing food security in the region.

## 2 Materials and methods

### 2.1 *Study design and analytical framework*

This study adopted a systematic review and quantitative synthesis approach to evaluate the epidemiological risks posed by major potato diseases and to assess the effectiveness and sustainability of management strategies across SSA. The analytical framework integrated multiple complementary components designed to capture both biophysical and institutional dimensions of disease management. These included a comparative country-level vulnerability analysis, a disease risk prioritisation matrix, a quantitative meta-analysis of disease management outcomes, a cost–effectiveness assessment of disease management strategies, and a comparative evaluation of technology adoption and sustainability. The integration of these analytical components allowed for a comprehensive evaluation of the disease landscape in SSA potato production systems and facilitated the identification of strategic interventions for improving disease management.

### 2.2 *Literature search and study selection*

A systematic literature search was conducted to identify relevant studies reporting on potato diseases and disease management interventions in SSA. The search was carried out using major scientific databases including Web of Science, Scopus, PubMed, and Google Scholar. Additional literature was identified from institutional repositories and reports produced by international agricultural research organisations such as the Food and Agriculture Organization (FAO) and the International Potato Center (CIP).

Search terms included combinations of keywords related to potato disease epidemiology and management, including "potato diseases," "late blight," "bacterial wilt," "potato seed systems," "integrated disease management," and "sub-Saharan Africa." Boolean operators were used to refine the search strings and ensure comprehensive coverage of the available literature. The search focused on publications from 2000 to 2024 in order to capture both historical and recent developments in potato disease management within the region.

### 2.3 *PRISMA framework*

The literature identification, screening, and selection process for this systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page *et al.*, 2021) to ensure transparency and reproducibility in the evidence synthesis process. The PRISMA flow diagram summarizing the study selection procedure is presented in Fig. 1. The initial search strategy was conducted across major academic databases and relevant scholarly repositories to identify peer-reviewed studies on potato diseases in SSA. The database search yielded 487 records. An additional 45 records were identified through reference lists, institutional reports, and grey literature sources to improve coverage of relevant evidence.

After removal of duplicate records, 512 unique studies remained and were screened based on titles and abstracts. Screening focused on studies relevant to potato disease epidemiology, management, and production systems within the SSA context. During this stage, 378 records were excluded because they did not meet the inclusion criteria, mainly due to lack of relevance, absence of empirical data, or focus outside SSA.

The remaining 134 studies underwent full-text assessment for eligibility. Full-text evaluation considered study objectives, methodological quality, geographic relevance, and

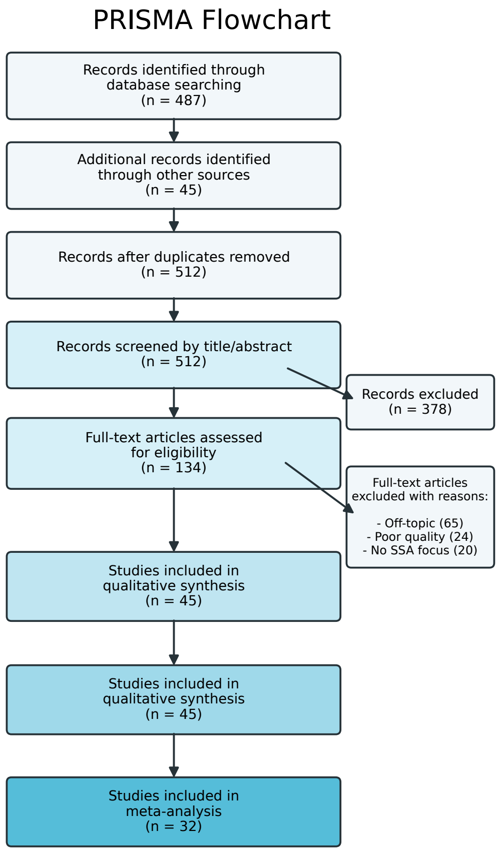


**Fig. 1:** *PRISMA flow diagram illustrating the study identification, screening, eligibility assessment, and inclusion process used in this systematic review.*

alignment with the review scope. Following eligibility assessment, 89 articles were excluded for one or more reasons, including off-topic focus, poor methodological quality, or lack of relevance to SSA. Some studies met multiple exclusion criteria.

After the screening process, 45 studies met the criteria for inclusion in the qualitative synthesis. Of these, 32 studies contained enough quantitative data on disease impacts or management outcomes to be included in the meta-analysis. These studies reported comparable measures such as yield losses, disease severity, or treatment effects, enabling quantitative synthesis across studies.

### 2.4 *Country-level production and vulnerability analysis*

Country-level potato production data were obtained from FAOSTAT agricultural statistics and complemented with national agricultural reports where necessary. Major potato-producing countries within SSA were selected based on their relative contribution to regional production volumes. To evaluate systemic vulnerability to potato diseases, a composite vulnerability index was developed using information extracted from the literature. The vulnerability index incorporated three principal indicators representing different dimensions of disease risk. These included the reported prevalence of major potato diseases, the strength of national seed systems including the availability of certified planting material, and the capacity of plant health management systems such as disease diagnostics, surveillance programs, and extension services. Each indicator was standardized and aggregated to produce a composite vulnerability score for each country. The resulting index allowed countries to be classified into three vulnerability categories: critical vulnerability, high vulnerability, and moderate vulnerability.

The vulnerability index was developed using information synthesized from the reviewed literature and expert-informed interpretation. Three indicators were considered: (i) prevalence of major potato diseases, (ii) strength of seed systems and access to certified seed, and (iii) plant health management capacity, including diagnostics, surveillance, and extension services. Each indicator was scored using a simple ordinal scale and combined to generate a comparative vulnerability score for each country. The index was intended to support regional comparison of disease vulnerability rather than provide an absolute epidemiological measure.

The relationship between national potato production volumes and disease vulnerability scores was visualized using a quadrant framework that enabled the identification of strategic intervention zones. This approach facilitated the comparison of production scale with systemic disease risk across countries.

### 2.5 *Disease risk assessment*

A disease risk assessment was conducted to prioritize the major potato diseases affecting potato production systems in SSA, including late blight, bacterial wilt, viral diseases, soft rot/blackleg, early blight, and powdery scab. Disease prioritisation was based on two main criteria: reported prevalence and economic importance. Prevalence estimates were derived from the frequency of disease reports in the reviewed studies, while economic importance was based on reported yield losses and production impacts. These parameters were combined within a two-dimensional risk matrix that classified diseases into four categories: high priority, emerging threat, moderate concern, and low priority. Management difficulty was represented by bubble size in the visualisation and was interpreted from literature describing pathogen persistence, control complexity, and availability of effective management options. The matrix was used as a comparative framework for prioritizing diseases across SSA potato systems.

### 2.6 *Meta-analysis of disease management outcomes*

A quantitative meta-analysis was conducted to assess the effectiveness of potato disease management interventions reported in the selected studies. The analysis focused on four key outcome indicators: potato yield improvement, reduction in disease incidence, changes in production costs, and adoption of improved disease management technologies. Relevant quantitative data were extracted from each study and standardized for comparative analysis. Effect sizes were calculated using reported percentage changes in the outcome variables relative to control or baseline conditions. Given the expected heterogeneity among studies arising from differences in agroecological conditions, experimental designs, disease management interventions, and study locations, a random-effects model was used to estimate pooled effects. Mean effect sizes and corresponding 95 % confidence intervals were calculated to determine the overall impact of disease management interventions across studies.

Between-study heterogeneity was assessed using the $I^2$ statistic, while variability in reported outcomes was summarized using standard deviations where available. These measures were used to evaluate the consistency and robustness of intervention effects across different production environments. Potential publication bias was assessed through visual examination of effect-size distributions and comparison of reported intervention outcomes among the included studies. This analytical approach provided a quantitative synthesis of the effectiveness of disease management strategies across potato production systems in SSA.

### 2.7 *Cost–effectiveness analysis of management strategies*

To compare the performance of alternative disease management strategies, a cost-effectiveness analysis was conducted. The analysis considered five major management approaches commonly reported in the literature: cultural practices, biological control, resistant varieties, chemical control, and certified seed systems. Each strategy was evaluated according to its relative cost, management effectiveness, and farmer adoption rate.

Cost and effectiveness scores were synthesized from published studies reporting disease control performance, implementation costs, and farmer adoption patterns. Cost levels were grouped into relative categories ranging from low to high input requirements, while effectiveness estimates were based on reported reductions in disease incidence and yield losses. The analysis was intended to compare relative trends among management strategies rather than provide a formal economic model.

Cost levels were classified using a standardized scale representing increasing levels of investment required for implementation. Management effectiveness was estimated based on reported reductions in disease incidence or yield losses. Adoption rates were derived from surveys and case studies describing the uptake of disease management technologies among farmers. These parameters were combined within a cost-effectiveness matrix in which management strategies were plotted according to their cost and effectiveness. An efficiency frontier was used to identify strategies that provided the highest effectiveness relative to their cost. Technology adoption and sustainability assessment

A comparative assessment of disease management technologies was conducted to evaluate the relationship between current adoption levels and long-term sustainability. Technologies included in the analysis encompassed both conventional and emerging approaches, including chemical fungicides, resistant varieties, certified seed systems, biological control agents, molecular diagnostics, artificial intelligence-based disease detection systems, and gene editing technologies. Sustainability scores were assigned based on environmental impact, long-term effectiveness, and compatibility with integrated disease management approaches. Adoption levels were estimated from reported farmer uptake and regional implementation trends described in the literature. These indicators were used to compare broad patterns in technology adoption and sustainability across SSA potato production systems. For each technology category, two key indicators were evaluated: the current adoption rate within SSA potato production systems and a sustainability score reflecting environmental impact, long-term effectiveness, and compatibility with integrated disease management approaches. Sustainability scores were assigned using a standardized scale in which higher values indicated greater environmental and long-term sustainability. The relationship between adoption levels and sustainability scores was visualized using comparative bubble plots.

### 2.8 Development of the strategic implementation roadmap

The strategic implementation roadmap was developed by synthesizing the findings from the vulnerability assessment, disease risk prioritisation, and technology evaluation components of the study. The roadmap outlines a phased framework for strengthening potato disease management systems in SSA over the period 2024–2037. Interventions were grouped according to priority level and expected implementation timeline. Early phases of the roadmap focus on strengthening foundational plant health systems, including certified seed systems and disease surveillance networks. Subsequent phases emphasize capacity building, deployment of improved technologies, expansion of integrated pest management strategies, and long-term climate-smart agricultural transformation.

### 2.9 Data analysis and visualisation

Data synthesis and graphical visualisations were conducted using standard statistical and scientific plotting tools. Visualisations were developed to illustrate relationships among production scale, disease vulnerability, management effectiveness, technology adoption, and strategic implementation timelines. These graphical analyses facilitated interpretation of the synthesized data and supported the identification of key patterns in disease risk and management strategies across SSA potato production systems. Consider to name the software used.

## 3 Results

### 3.1 Potato production context and disease vulnerability across SSA

Potato production and disease vulnerability vary substantially across major SSA producing countries (Fig. 2). The comparative analysis integrated national production statistics with a composite vulnerability index derived from disease prevalence, seed system integrity, and management capacity indicators reported in the reviewed literature.

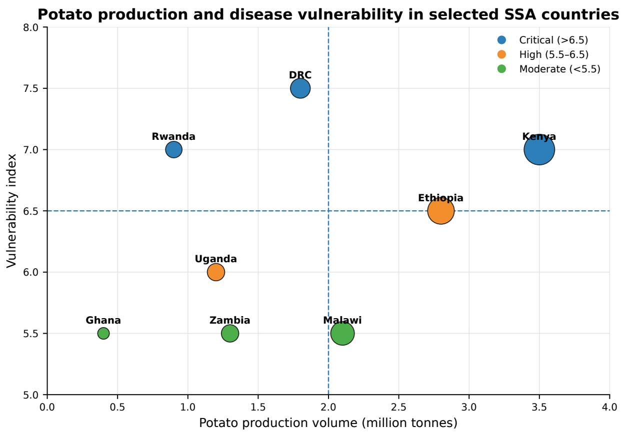


**Fig. 2:** *Relationship between potato production volume and disease vulnerability index across major sub-Saharan African potato-producing countries. Bubble size represents relative production scale, while colour coding indicates vulnerability categories.*

The quadrant framework identified two key strategic intervention zones. The high-priority zone, characterized by both high production and high vulnerability, includes Kenya and Ethiopia, indicating that disease management investments in these systems could generate substantial regional benefits. In contrast, the emerging-need zone, defined by lower production but high vulnerability, includes Rwanda and the Democratic Republic of Congo (DRC), where strengthening disease management capacity may support future production growth.

Kenya emerged as the largest producer among the analysed countries, producing approximately 3.5 million metric tons with a vulnerability index of 7.0, placing it within the critical vulnerability category (>6.5). Similarly, the Democratic Republic of Congo (DRC) exhibited the highest vulnerability score (≈7.5) despite producing approximately 1.8 million metric tons, suggesting substantial systemic weaknesses in plant health infrastructure and seed system capacity. Rwanda also displayed high vulnerability (≈7.0) despite relatively smaller production volumes (≈0.9 million metric tons).

Ethiopia and Uganda fall within the high vulnerability category (5.5–6.5). Ethiopia produces approximately 2.8 million metric tons with a vulnerability index of 6.5, while Uganda produces ≈1.2 million metric tons with a vulnerability score of 6.0. In contrast, Malawi, Zambia, and Ghana exhibit comparatively lower vulnerability levels (<5.5), although disease risks remain present across all systems.

### 3.2 Risk prioritisation of major potato diseases

The risk assessment matrix revealed clear differences in the epidemiological importance of major potato diseases in SSA (Fig. 3). Diseases were classified according to their prevalence and economic importance, enabling prioritisation for management interventions. Late blight emerged as the most critical disease, occupying the high-priority quadrant with both high prevalence (≈85 %) and high economic importance (≈95). The large bubble size indicates substantial management difficulty, reflecting rapid pathogen evolution, favourable climatic conditions, and dependence on repeated fungicide applications. Bacterial wilt also fell within the high-priority category, with prevalence around 75 % and economic importance near 80, highlighting its importance as a major constraint due to its soil-borne persistence and limited management options. Viral diseases were positioned within the moderate concern quadrant, characterised by high prevalence (≈70 %) but lower economic impact (≈60). Soft rot/blackleg appeared near the threshold between moderate and high economic importance, with prevalence around 60 % and an importance score of ≈65. In contrast, early blight and powdery scab were located within the low-priority quadrant,

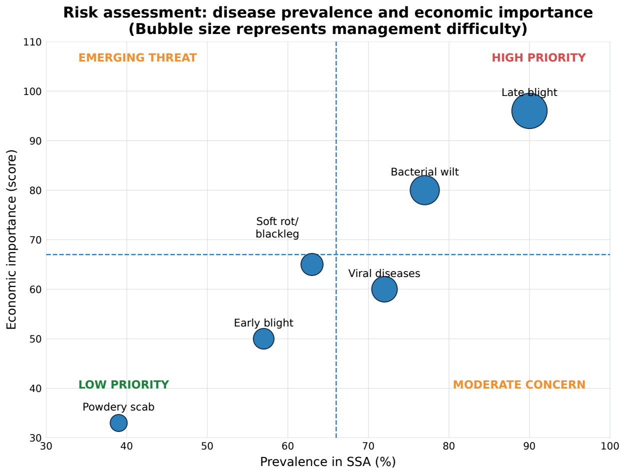


**Fig. 3:** *Risk assessment matrix of major potato diseases in sub-Saharan Africa. The relationship between disease prevalence (%) and economic importance (score) is shown. Bubble size represents management difficulty, while dashed lines divide the matrix into four priority categories (represented as quadrants): high priority, emerging threat, moderate concern, and low priority.*

with lower prevalence and economic impact relative to the most damaging diseases.

### 3.3 Meta-Analysis of disease management outcomes

The meta-analysis revealed consistent positive impacts of disease management interventions across SSA production systems (Fig. 4). Across the analysed studies, interventions produced a mean yield increase of 28.0 % (±18.0), reflecting the aggregated benefits of improved seed systems, resistant varieties, and integrated disease management strategies. The strongest effect was observed for disease reduction, with a pooled reduction of 42.0 % (±32.0). However, the wide confidence interval indicates substantial variation across agro-ecological conditions and management systems. Economic benefits were also substantial. Disease management interventions resulted in a mean cost reduction of 35.0 % (±25.0), reflecting reduced yield losses and lower input expenditures. Technology adoption increased by an average of 38.0 % (±28.0) following intervention implementation. Environmental improvements were smaller but measurable, with a pooled environmental benefit score of 6.5 (±4.2), reflecting reduced fungicide use and improved sustainability associated with integrated management systems.

### 3.4 Cost–effectiveness of disease management strategies

The comparative assessment of management strategies demonstrated clear trade-offs between effectiveness, cost, and adoption levels (Fig. 5). Cultural practices represented the lowest-cost option and achieved moderate effectiveness

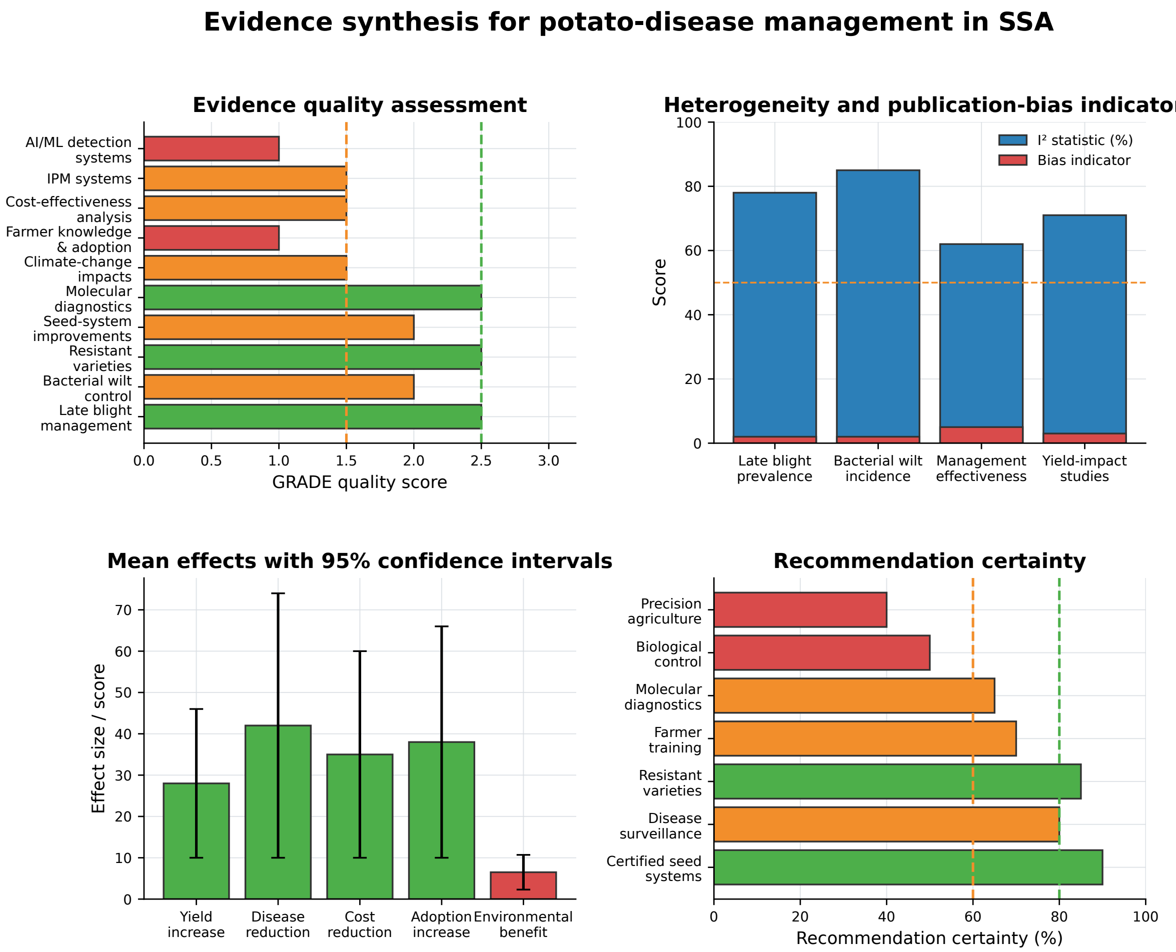


**Fig. 4:** *Meta-analysis outcome measures showing pooled mean effects and variability (95 % confidence intervals) across studies evaluating potato disease management interventions in sub-Saharan Africa.*

(≈60 %), while exhibiting the highest farmer adoption rates. Biological control showed moderate effectiveness (≈65 %) but limited adoption, likely due to availability constraints and technical requirements. Resistant varieties demonstrated high effectiveness (≈80 %) at moderate cost levels, with moderate adoption rates influenced by seed availability and breeding progress. Chemical control showed high effectiveness (≈85 %) but required higher input costs. The most effective strategy was certified seed systems, achieving approximately 90 % management effectiveness. However, adoption remains constrained by the higher costs and limited availability of certified seed. The efficiency frontier highlights resistant varieties, chemical control, and certified seed systems as the most efficient strategies for improving disease management outcomes.

### *3.5 Technology adoption and sustainability*

The comparison of disease management technologies revealed a clear inverse relationship between current adoption levels and sustainability performance (Fig. 6). Conventional technologies with lower sustainability scores show higher adoption rates, whereas more sustainable technologies remain underutilised. Chemical fungicides exhibited the highest adoption rate (≈70 %) but the lowest sustainability score (2), reflecting strong dependence on chemical disease control across SSA production systems. In contrast, resistant varieties, certified seed systems, and biological control technologies demonstrated high sustainability scores (8—9) but comparatively lower adoption levels (15–35 %). These technologies represent environmentally sustainable management options whose uptake remains limited by seed availability, cost, and technical capacity.

Advanced technologies such as molecular diagnostics, AI-based disease detection, and CRISPR-based gene editing displayed very low adoption levels (2–12 %), reflecting technological, regulatory, and institutional barriers. These results highlight a significant innovation–adoption gap between sustainable technologies and current farming practices in SSA.

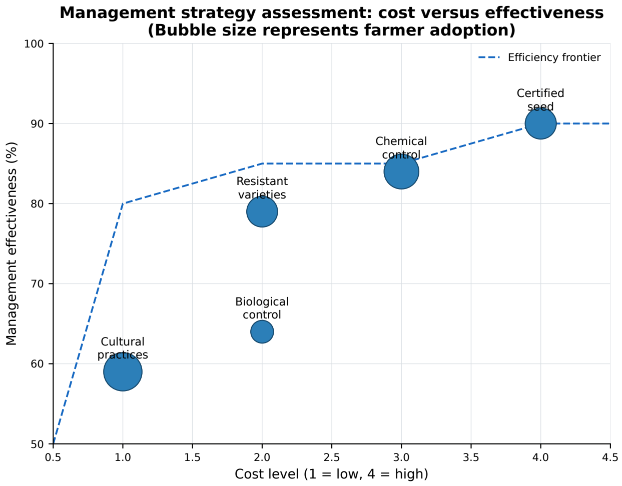


**Fig. 5:** *Cost–effectiveness of potato disease management strategies. The relationship between cost level (1 = low, 4 = high) and management effectiveness (%) for different control strategies is shown. Bubble size represents farmer adoption rate, and the dashed line indicates the efficiency frontier, highlighting strategies that provide the best effectiveness relative to cost.*

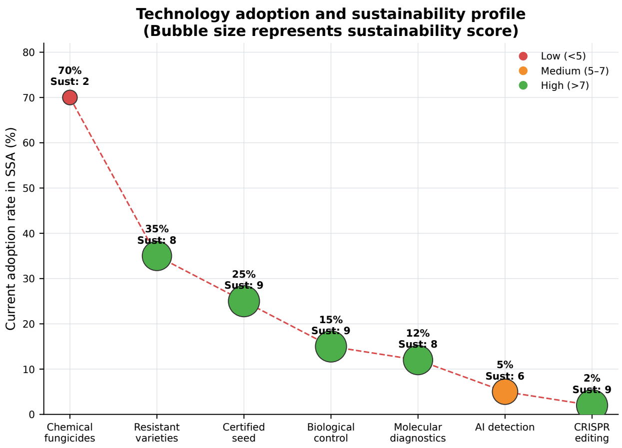


**Fig. 6:** *Technology adoption and sustainability profile of potato disease management technologies in sub-Saharan Africa.*

## 4 Discussion

### *4.1 Systemic vulnerability of potato production systems in sub-Saharan Africa*

The comparative analysis of potato production and disease vulnerability highlighted substantial heterogeneity in the resilience of potato production systems across SSA. Countries such as Kenya and Ethiopia fall within the high-priority quadrant where both production scale and vulnerability are high, indicating that disease outbreaks in these systems could have major implications for regional food security. Similar patterns have been reported in global assessments of crop health systems, where productivity gains are often not accompanied by parallel improvements in plant health infrastructure, including surveillance systems, diagnostic capacity, and certified seed availability (Munkvold *et al.*, 2025; Yeboah *et al.*, 2025). The results further showed that disease vulnerability is not strictly correlated with production scale. Countries such as the Democratic Republic of Congo and Rwanda exhibit high vulnerability indices despite comparatively smaller production volumes. This finding suggests that structural weaknesses in seed systems, diagnostic capacity, and extension services can expose production systems to high disease risks even at relatively small scales. Institutional and infrastructural constraints have been widely recognized as major drivers of disease vulnerability in African agricultural systems (Devaux *et al.*, 2021) From a regional perspective, these findings imply that strengthening plant health systems is essential for improving resilience in potato production. Investments in certified seed systems, disease surveillance networks, and diagnostic infrastructure can significantly reduce disease spread and improve production stability. Such institutional improvements are increasingly recognized as critical components of agricultural transformation strategies in developing regions (Beatrice *et al.*, 2023; Sharma *et al.*, 2025).

### *4.2 Epidemiological prioritisation of major potato diseases*

The risk assessment matrix clearly identified late blight and bacterial wilt as the most critical diseases affecting potato production systems in SSA. Late blight, caused by Phytophthora infestans, remains one of the most destructive diseases of potato worldwide due to its rapid epidemic development, high dispersal capacity, and ability to evolve resistance to control measures (Hari *et al.*, 2025).

The placement of late blight in the high-priority quadrant is therefore consistent with its epidemiological characteristics. In many potato-growing environments, favourable climatic conditions combined with limited access to resistant varieties or fungicides allow epidemics to spread rapidly, leading to severe yield losses (Khalid *et al.*, 2026; Wenninger & Rashed, 2024)

Bacterial wilt represents another major constraint due to its soil-borne persistence and its ability to survive in infected soils for extended periods. Once established, the pathogen can cause significant yield losses and is difficult to eradicate without integrated management approaches that include resistant varieties, crop rotation, and clean planting material (van der Waals & Krüger, 2020).

In contrast, viral diseases and soft rot/blackleg appear to represent intermediate threats within the regional disease landscape. Their widespread occurrence suggests that they contribute to gradual yield reductions rather than acute epidemic outbreaks (Wenninger & Rashed, 2024). Early blight and powdery scab were positioned within the low-priority quadrant, although localized impacts may still occur under favourable environmental conditions (Wenninger & Rashed, 2024).

The prioritisation of diseases based on prevalence and economic impact aligns with broader plant pathology research emphasizing the importance of targeted disease management strategies in optimizing resource allocation for plant health interventions (Munyaneza & Bizimungu, 2022; Ojiambo, 2025).

### *4.3 Effectiveness of disease management interventions*

The meta-analysis demonstrates that disease management interventions can significantly improve potato production outcomes across SSA. The observed average yield increase of approximately 28 % highlights the substantial productivity gains that can be achieved through improved disease control strategies. These findings are consistent with global analyses showing that plant pathogens remain among the most important constraints to crop productivity. Recent estimates suggest that pests and diseases cause yield losses ranging from 13 % to 22 % in major food crops globally (Chakrabarti *et al.*, 2022; Wenninger & Rashed, 2024). The pooled disease reduction effect of approximately 42 % further confirms the effectiveness of integrated disease management strategies. However, the variability observed across studies suggests that intervention outcomes depend strongly on agro-ecological conditions, pathogen pressure, and management practices across different production systems (Munyaneza & Bizimungu, 2022; Ojiambo, 2025).

Economic benefits were also substantial, with disease management interventions reducing production costs by approximately 35 %. These findings suggest that improved disease management not only enhances productivity but also improves economic efficiency by reducing crop losses and minimizing input expenditures (Devaux *et al.*, 2021).

Environmental benefits were smaller but still measurable, reflecting reduced reliance on chemical pesticides and improved sustainability associated with integrated disease management strategies (Khalid *et al.*, 2026)

### *4.4 Trade-offs between effectiveness, cost, and adoption*

The cost–effectiveness analysis highlights important trade-offs between the performance of disease management technologies and their accessibility to farmers. Low-cost strategies such as cultural practices (for example; crop rotation, use of clean seed, sanitation of tools, and proper field management) exhibit the highest adoption levels despite relatively modest effectiveness. This pattern reflects the financial constraints faced by many smallholder farmers, who often prioritize affordability and ease of implementation when selecting management strategies (Chaurasiya *et al.*, 2025). More effective interventions such as resistant varieties and certified seed systems require greater institutional support and investment. Although these technologies offer higher disease control potential, adoption remains constrained by the availability and affordability of improved seed systems (Devaux *et al.*, 2021).

Chemical control strategies represent an intermediate position within this trade-off structure. While fungicides can provide effective disease suppression, their costs and environmental impacts raise concerns regarding long-term sustainability and pathogen resistance development (Phungula *et al.*, 2025) . These findings emphasize the need for integrated disease management strategies that combine multiple approaches to balance effectiveness, affordability, and sustainability.

### *4.5 Technology adoption and the sustainability gap*

One of the most notable findings of this study is the inverse relationship between technology adoption and sustainability performance. Conventional chemical control strategies exhibit the highest adoption levels despite having the lowest sustainability scores. This pattern reflects the immediate effectiveness and widespread availability of chemical disease control options (Phungula *et al.*, 2025).

In contrast, technologies with high sustainability potential, including resistant varieties, biological control agents, and certified seed systems, show comparatively lower adoption levels. This disparity indicates the presence of a significant innovation–adoption gap within SSA potato production systems (Devaux *et al.*, 2021). Limited seed multiplication capacity, weak extension services, and financial constraints are major barriers limiting the adoption of improved technologies in many smallholder farming systems (Munkvold *et al.*, 2025). Additionally, advanced technologies such as molecular diagnostics, artificial intelligence-based disease detection, and gene editing remain largely confined to research institutions due to infrastructure and regulatory limitations (Öztekin & Almas, 2025; Kempenaar *et al.*, 2026;). Addressing this innovation–adoption gap will require coordinated investments in seed system development, extension services, and farmer training programs to improve access to sustainable disease management technologies (Chaurasiya *et al.*, 2025; Hua *et al.*, 2026). Strategic implications for disease management in SSA

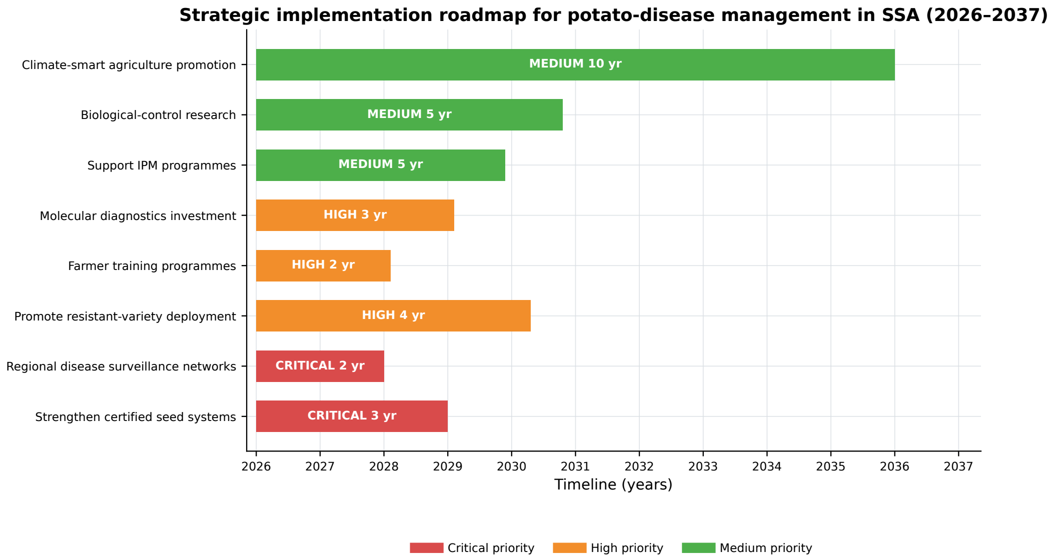


**Fig. 7:** *Strategic implementation roadmap for potato disease management in sub-Saharan Africa (2026–2037).*

The strategic implementation roadmap proposed in this study highlights the importance of a phased approach to strengthening potato disease management systems in SSA. The prioritisation of certified seed systems and disease surveillance networks reflects the foundational role of these components in effective plant health systems (Munkvold *et al*., 2025).

Clean seed systems are widely recognized as one of the most effective strategies for reducing the spread of seed-borne pathogens, while surveillance systems enable early detection and rapid response to emerging disease outbreaks (Sharma *et al*., 2018; Andrade-Piedra *et al*., 2025). Subsequent phases of the roadmap emphasize farmer training, deployment of resistant varieties, and strengthening diagnostic infrastructure. These interventions are essential for translating research advances into practical management solutions that can be implemented at the farm level (Devaux *et al*., 2021; Munyaneza & Bizimungu, 2022).

The final phase focuses on climate-smart agriculture, recognizing that climate change is expected to influence the distribution and severity of plant diseases worldwide. Adaptive disease management strategies will therefore be essential for maintaining production stability under changing environmental conditions (Munyaneza & Bizimungu, 2022; Khalid *et al*., 2026).

### *4.6 A conceptual framework for phased disease management in SSA*

This study proposes a strategic implementation framework for potato disease management in SSA from 2026 to 2037 (Fig. 7). In the immediate phase (2026–2028), priority should be given to urgent plant health interventions, particularly strengthening certified seed systems, establishing regional disease surveillance networks, and rolling out farmer training programmes. The short- to medium-term phase (2026–2030) focuses on technology deployment and capacity enhancement through investment in molecular diagnostics and the promotion of resistant potato varieties. Strengthening diagnostic infrastructure will improve the rapid detection and monitoring of emerging pathogens, while the deployment of resistant cultivars will provide a sustainable means of reducing disease pressure and improving productivity. Together, these interventions will enhance farmer-level disease management capacity and strengthen overall plant health systems.

The medium-term phase (2026–2031) emphasizes the expansion of integrated pest management (IPM) programmes and biological control research. These interventions aim to reduce dependence on chemical pesticides by promoting environmentally sustainable and economically viable disease management approaches. The integration of IPM strategies with biological control technologies is expected to improve long-term system resilience while minimizing environmental and public health risks associated with excessive pesticide use.

The long-term phase (2027–2037) focuses on the promotion of climate-smart agricultural practices to enhance the resilience of potato production systems to climate variability, emerging disease threats, and changing environmental conditions. This phase supports the adoption of sustainable production practices that improve resource-use efficiency, maintain soil health, and strengthen adaptive capacity across farming communities in SSA.

The roadmap underscores the importance of a phased and integrated approach to potato disease management, beginning with the establishment of robust surveillance systems, strengthened certified seed systems, and farmer capacity development from 2026. These foundational investments are followed by the deployment of advanced diagnostic technologies, resistant varieties, IPM programmes, and biological control interventions, culminating in the long-term adoption of climate-smart agricultural practices. Such a sequential strategy provides a practical pathway for improving potato productivity, reducing disease-related losses, and enhancing the sustainability of potato production systems across SSA.

The findings of this study further demonstrate that effective disease management strategies have substantial potential to increase potato productivity, reduce production risks, and improve farm profitability. Consequently, strengthening plant health systems through improved seed systems, disease surveillance networks, diagnostic capacity, and sustainable disease management technologies will be essential for unlocking the full food security and economic potential of potato production in SSA (Ojiambo, 2025).

## 5 Conclusions

This systematic review and meta-analysis demonstrated that potato diseases remain a major constraint to productivity, profitability, and food security across SSA. The findings identified late blight and bacterial wilt as the most critical threats, while revealing substantial variation in disease vulnerability among major potato-producing countries. Despite these challenges, disease management interventions can significantly improve production outcomes, with evidence showing notable gains in yield, disease suppression, and economic returns.

The study further highlighted a persistent gap between the availability of sustainable disease management technologies and their adoption by farmers. While certified seed systems, resistant varieties, and integrated disease management approaches offer the greatest long-term benefits, their uptake remains constrained by weaknesses in seed systems, diagnostic capacity, extension services, and institutional support.

Strengthening plant health systems through investment in certified seed production, disease surveillance, diagnostic infrastructure, farmer capacity building, and climate-smart disease management will be essential for enhancing resilience and productivity in potato production systems. A coordinated regional approach involving researchers, policymakers, private sector actors, and farming communities is therefore critical to reducing disease-related losses and unlocking the full potential of potato as a strategic food security and livelihood crop in SSA.

## 6 Recommendations

From this systematic review, the following recommendations are suggested:

*Strengthen seed systems and access to clean planting material*

- Expand access to certified, disease-free seed through decentralized seed multiplication systems, community seed hubs, and public–private partnerships.
- Promote regional harmonisation of seed certification standards to facilitate cross-border movement of quality seed and improved germplasm.
- Increase investment in early-generation seed production technologies, including aeroponics, screenhouses, and cold storage facilities.

*Accelerate development and deployment of resistant varieties*

- Strengthen national and regional potato breeding programmes to enhance resistance against major diseases, particularly late blight and bacterial wilt.
- Streamline variety testing and release procedures to facilitate timely dissemination of improved cultivars.

*Scale integrated disease management approaches*

- Enhance farmer capacity through strengthened extension services and training on integrated disease management practices.
- Promote sustainable disease control by combining crop rotation, field sanitation, resistant varieties, biological control, and responsible fungicide use.
- Support community-based disease management and scale up validation and commercialisation of biological control technologies for smallholder farmers.

*Invest in surveillance, diagnostics, and digital agriculture*

- Strengthen disease surveillance and preparedness by expanding diagnostic infrastructure, laboratory capacity, and regional monitoring and information-sharing systems.
- Leverage digital innovation through AI-based disease detection, climate-informed forecasting, mobile advisory tools, and digital extension services to provide timely, localized disease management information to farmers.

*Strengthen policy and institutional support*

- Strengthen plant health systems through increased investment in phytosanitary services, diagnostic laboratories, quality assurance mechanisms, and regional disease surveillance and response networks.
- Promote sustainable disease management by supporting certified seed systems and institutionalizing continuous farmer training on disease identification, seed quality, and integrated disease management practices.

*Ethical statement*

This study is a systematic review and meta-analysis based exclusively on previously published data obtained from peer-reviewed articles and publicly available sources. No human participants, animals, or experimental plant materials were involved; therefore, ethical approval and informed consent were not required. The review followed established reporting standards, including the PRISMA 2020 Statement. All data were accurately extracted and appropriately cited, and the authors complied with accepted principles of research integrity.

*Conflict of interest*

The authors declare no conflict of interest.

## References

Andrade-Piedra, J. L., Sharma, K., Kroschel, J., Ogero, K., Kreuze, J., Legg, J. P., Kumar, P. L., Spielman, D. J., Navarrete, I., Perez, W., Atieno, E., & Garrett, K. A. (2025). Phytosanitary Challenges and Solutions for Roots and Tubers in the Tropics. In *Annual Review of Phytopathology*. volume 63. doi: 10.1146/annurev-phyto-021722-030316.

Beatrice, C., Stephen, W. M., Joel, K. N., & Atsiaya, O. G. (2023). Influence of plant health clinic training services on potato production: Evidence from smallholder farmers in molo sub-county, Kenya. *Journal of Agricultural Extension and Rural Development*, 15(1). doi: 10.5897/jaerd2022.1357.

Chakrabarti, S. K., Sharma, S., & Shah, M. A. (2022). Potato Pests and Diseases: A Global Perspective. In *Sustainable Management of Potato Pests and Diseases*. doi: 10.1007/978-981-16-7695-6_1.

Chaurasiya, P., Singh, M., Verma, R., Kumar, S., Maurya, S., Singh, R., & Pandey, O. C. (2025). Enhancing Potato growth and economic returns through optimized integrated nutrient management (*Solanum tuberosum* L.). *International Journal of Research in Agronomy*, 8(3S). doi: 10.33545/2618060x.2025.v8.i3sd.2698.

De Vries, M., Ter Maat, M., & Lindhout, P. (2016). The potential of hybrid potato for East-Africa. *Open Agriculture*, 1(1). doi: 10.1515/opag-2016-0020.

Devaux, A., Goffart, J.-P., Kromann, P., Andrade-Piedra, J., Polar, V., & Hareau, G. (2021). The Potato of the Future: Opportunities and Challenges in Sustainable Agrifood Systems. *Potato Research*, 64(4). doi: 10.1007/s11540-021-09501-4.

Hari, A., Echchgadda, G., Benjelloun, M., Lahmamsi, H., Belabess, Z., Laasli, S. E., Mokrini, F., Lazraq, A., & Lahlali, R. (2025). Sustainable plant-based control strategies for late blight disease of potato. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*, 20(1). doi: 10.1079/cabireviews.2025.0001.

Hua, J., Li, Y., Li, Z., Ma, D., He, S., Li, C., Zalucki, M. P., & Gao, Y. (2026). Advancing towards a sustainable green management system (SGMS) for the sweet potato weevil, *Cylas formicarius*: a synthesis of traditional knowledge and modern innovations. *Pest Management Science*, 82(4), 2825–2837. doi: 10.1002/ps.70556.

Kempenaar, C. C., Sijbrandij, F. F. D., Been, T. T. H., van Boheemen, K. K., Booij, J. J. A., van Evert, F. F. K., Teklu, M. G. M. G., Kessel, G. G. J. T., Kocks, C. C. G., Lugtenburg, C. C., van der Meer, A. A., Molendijk, L. L. P. G., van Oort, P. P. A. J., Tielen, J. J. J. H., & van der Wal, T. T. (2026). Towards Data-Driven Precision Crop Management of Potato. *Potato Research*, 69(1). doi: 10.1007/s11540-025-09996-1.

Khalid, R., Riaz, U., Khan, M. U., Ali, M., & ul Haq, T. (2026). Impact of Climate Change on Plant Pathogens, Disease and Food Security. In *Artificial Intelligence and Data Sciences for Precision Agriculture*. doi: 10.1007/978-3-032-12770-9_9.

Kiige, J. K., Kavoo, A. M., Mwajita, M. R., & Kiirika, L. M. (2026). Prevalence, Severity, and Distribution of Potato Cyst Nematode in Nyandarua and Nyeri Counties, Kenya. *Journal of Agricultural Sciences – Sri Lanka*, 21(1). doi: 10.4038/jas.v21i1.11148.

Laizer, H., & Mduma, N. (2025). Irish potato imagery dataset for detection of early and late blight diseases. *Data in Brief*, 60. doi: 10.1016/j.dib.2025.111549.

Mickiewicz, B., Volkova, E., & Jurczak, R. (2022). The Global Market for Potato and Potato Products in the Current and Forecast Period. *European Research Studies Journal*, XXV(3). doi: 10.35808/ersj/3062.

Munkvold, G., Du Toit, L., & Dunkle, R. (2025). Seed Pathology: Challenges and Advances in Ensuring a Safe Global Seed Supply. In *Annual Review of Phytopathology*. volume 63. doi: 10.1146/annurev-phyto-121423-093855.

Munyaneza, J. E., & Bizimungu, B. (2022). Management of potato pests and diseases in Africa. In *Insect Pests of Potato: Global Perspectives on Biology and Management*. doi: 10.1016/B978-0-12-821237-0.00016-0.

Muthoni, J., & Shimelis, H. (2022). An overview of potato production in Africa. In *Potato Production Worldwide*. doi: 10.1016/B978-0-12-822925-5.00020-7.

Ojiambo, P. S. (2025). Insect pest and plant disease management in horticultural crop production: recent insights provide opportunities for improved control. *Frontiers in Horticulture*, 4. doi: 10.3389/fhort.2025.1605035.

Öztekin, A., & Almas, K. (2025). Deep Learning based Disease Detection from Potato Leaf Images. *Balkan Journal of Electrical and Computer Engineering*, 13(1). doi: 10.17694/bajece.1649068.

Phungula, N. P. M., Hadebe, S. T., Schulte-Geldermann, E., Sithole, L., & Ngobese, N. Z. (2025). The response of potato late blight to the integration of selected potato cultivars, fungicides and mulch at different levels, and localities. *European Journal of Plant Pathology*, 172(3). doi: 10.1007/s10658-025-03028-x.

Sharma, K., Shawkat, B., Miethbauer, T., & Schulte-Geldermann, E. (2018). *Strategies for bacterial wilt (*Ralstonia solanacearum*) management in potato field: Farmers' guide*. Technical Report International Potato Center.

Sharma, N., Mahawar, L., Mishra, A., & Albrectsen, B. R. (2025). Microbial contributions to plant growth and stress tolerance: Mechanisms for sustainable plant production. *Plant Stress*, 17. doi: 10.1016/j.stress.2025.100966.

Tiwari, J. K., Buckseth, T., Zinta, R., Bhatia, N., Dalamu, D., Naik, S., Poonia, A. K., Kardile, H. B., Challam, C., Singh, R. K., Luthra, S. K., Kumar, V., & Kumar, M. (2022). Germplasm, Breeding, and Genomics in Potato Improvement of Biotic and Abiotic Stresses Tolerance. *Frontiers in Plant Science*, 13. doi: 10.3389/fpls.2022.805671.

van der Waals, J. E., & Krüger, K. (2020). Emerging potato pathogens affecting food security in southern Africa: Recent research. *South African Journal of Science*, 116(11). doi: 10.17159/sajs.2020/8055.

Wenninger, E. J., & Rashed, A. (2024). Biology, Ecology, and Management of the Potato Psyllid, Bactericera cockerelli (Hemiptera: Triozidae), and Zebra Chip Disease in Potato. *Annual Review of Entomology*, 69, 139–157. doi: 10.1146/annurev-ento-020123-014734.

Yeboah, A., Tetteh, R., Mensah, E. O., Bruce, B. B., Tagoe, A., & Boateng, I. D. (2025). Non-destructive Techniques in Crop Germplasm Conservation: Advances and Implications for Global Food Security. *Journal of Agriculture and Food Research*, 24, 102435. doi: 10.1016/j.jafr.2025.102435.