

# Evaluation of the Effectiveness of Strategies to Control Banana Bacterial Wilt in South Kivu: Towards Sustainable and Inclusive Solutions

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**Abstract:-** Bacterial wilt, caused by *Xanthomonas campestris* pv. *musacearum*, threatens banana production in the tropical and intertropical zone of Africa, where this crop plays a very crucial role in food and socioeconomic security. South Kivu located in the East of the Democratic Republic of Congo is particularly affected, which compromises the livelihoods of local communities. Factors such as poor climatic conditions and infrastructure exacerbate the situation. In this study, we evaluate existing control strategies to reduce the impact of the disease. The study is based on a systematic review of academic documents and institutional reports. It analyzes bacterial wilt management strategies, their effectiveness and the actors involved. The strategies include chemical treatments, the introduction of resistant varieties, biological methods, and integrated disease management. Although chemical treatments offer short-term control, they have long-term limitations. Resistant varieties and biological methods have shown potential, but their adoption is hampered by economic and logistical obstacles. Integrated disease management shows promise but requires increased collaboration among local stakeholders. Recommendations include improving research, access to resistant varieties, optimizing organic methods, strengthening integrated management practices, and better financial and institutional support for farmers. These actions should strengthen the fight against bacterial wilt and ensure food security in the region.

**Keywords:-** Efficiency, Strategy, Banana Bacterial Wilt.

## I. INTRODUCTION

Banana bacterial wilt, caused mainly by *Xanthomonas campestris* pv. *musacearum*, is one of the most serious and feared plant pathogenic diseases in banana plantations worldwide. In Africa, this disease poses a serious threat to banana production, a crucial staple food for millions of people, particularly in sub-Saharan Africa where banana cultivation is essential for food security and smallholder farmers' incomes (FAO, 2020; Gichuru et al., 2016).

In the Democratic Republic of Congo (DRC), particularly in the South Kivu province, banana is a strategic

crop, both for the subsistence of rural communities and for the local economy. Indeed, banana is a main source of food and income for many households (FAO, 2020; Makule et al., 2017). However, bacterial wilt has caused considerable losses in banana yields, thus threatening the food security of local populations and the economic stability of the region (Karamura et al., 2018; Bertsch et al., 2020).

Wilt problem is particularly complex in South Kivu due to several factors, including specific environmental conditions, inadequate agricultural practices, and weak sanitary and phytosanitary infrastructure (Tshilumbu et al., 2017). The disease manifests itself through rapid leaf wilting and root degradation, leading to significant yield decline and premature death of banana plants. This situation is exacerbated by the lack of resistant varieties and limited access to effective phytosanitary treatments (Bertsch et al., 2020; Nchinda et al., 2021). In addition, the rapid spread of the pathogen is a major challenge for control efforts, making complete eradication of the disease difficult (Gichuru et al., 2016).

In the face of these challenges, it is crucial to evaluate the strategies implemented to combat bacterial wilt in this region. Although some approaches, such as the use of resistant varieties, agroecological management, and biological control, have shown positive results in other regions of Africa (Nchinda et al., 2021; Gichuru et al., 2016), their applicability and effectiveness in the specific context of South Kivu have not been sufficiently studied. Furthermore, knowledge regarding the impact of local, national, and international actors in the fight against this disease remains limited, and better coordination seems necessary to strengthen farmers' resilience to this threat (FAO, 2020; Makule et al., 2017).

The main hypothesis of this study is that integrated strategies, combining biological, chemical and agroecological methods, as well as the introduction of resistant varieties, can significantly reduce the impact of bacterial wilt in South Kivu. However, the effectiveness of these strategies depends on various factors, such as farmers' adherence to new practices, resource availability and the involvement of local and international actors in the

implementation of interventions ( Bertsch et al., 2020 ; Nchinda et al., 2021 ).

The main objective of this study is to evaluate current approaches used to control banana bacterial wilt in South Kivu, analyze their effectiveness, and propose practical recommendations to improve eradication efforts. A thorough analysis of these strategies will help to better understand local dynamics and develop more adapted and sustainable solutions to control bacterial wilt, thus contributing to food security and agricultural development in this vulnerable region (FAO, 2022; Tshilumbu et al., 2017).

## II. METHODOLOGY

The study is based on a systematic or bibliographic review, aiming to identify and evaluate strategies for controlling banana bacterial wilt in South Kivu. It is based on institutional reports, dissertations, theses, scientific articles, and technical documents to analyze approaches to managing this disease.

Selection criteria include publication period (10-15 years), geographical relevance (South Kivu and similar regions), quality of studies (academic publications and validated institutional reports), and bacterial wilt management approach (chemical, biological, agronomic, genetic methods).

Data collection was carried out through searches in academic databases (Google Scholar , Scopus Research4life) and archives of local institutions. The selected documents were extracted according to the objectives of the study: identification of control approaches, actors involved, results and challenges.

Data analysis was thematic and comparative, including:

- *Synthesis of Approaches*

Classification of control strategies according to appropriate categories.

- *Effectiveness Evaluation*

Analysis of the effectiveness of each strategy in the context of South Kivu and neighboring regions.

- *Identification of Actors*

Identification of actors (government, NGOs, research institutions, local communities) and analysis of their role.

- *Comparison of Results*

Comparison of different studies to identify best practices.

Some limitations in this methodology included the availability of documents (especially in areas with few digital archives), bias in some studies (related to local contexts or funding), and the lack of recent data . However, efforts were made to address these limitations by consulting various sources and including recent unpublished studies.

The results were synthesized in the form of a systematic review, structuring the data around the control strategies, the results obtained, the actors involved and recommendations for future interventions.

## III. RESULTS

### A. Approaches to combat banana bacterial wilt in South Kivu

Banana bacterial wilt is one of the main agricultural threats in South Kivu , a region of Central Africa where banana cultivation plays a major role in the rural economy. Several control approaches have been tested to limit the spread of the disease, but their success varies depending on local contexts, available resources, and the actors involved. The main approaches identified in the studies are presented in the table below:

Table 1 The Main Approaches Identified in the Studies

Approach	Benefits	Boundaries
<b>1. Chemical Treatments</b>	- Temporary reduction in the spread of the pathogen. - Initial alleviation of symptoms ( Mugisha et al., 2019).	- Variable efficacy depending on climatic conditions and application methods. - High costs and limited availability of products, making large-scale adoption difficult. - Appearance of cross-resistance. ( Karamura et al., 2018).
<b>2. Introduction of Resistant Varieties</b>	- Long-lasting protection against disease, reduced spread of wilt ( Bertsch et al., 2020). - Increased resistance to local <i>Xanthomonas</i> strains (IRAD).	- Low diffusion of resistant varieties due to high costs and lack of distribution infrastructure. - Slow adoption of new technologies by producers.
<b>3. Biological Methods</b>	- Promising results in reducing the spread of bacterial wilt ( Nchinda et al., 2021). - Use of antagonistic microorganisms to inhibit the growth of the pathogen.	- Results vary depending on local conditions (climate, regularity of applications). - Need for long-term studies to confirm effectiveness. - Lack of resources and training for local producers.
<b>4. Integrated Disease Management (IDM) Strategies</b>	- Reduction of dependence on chemicals. - Optimization of available resources. - Sustainable approach minimizing environmental impacts.	- Complex coordination between local actors. - Need for access to varied resources and strong awareness among farmers. - Long-term monitoring and evaluation required ( Mugisha et al., 2019).

Approaches to combating banana bacterial wilt in South Kivu show that, although significant progress has been made in research and experimentation, there are still challenges to overcome. Chemical treatments, although effective in the short term, have significant limitations related to their sustainability and environmental risks. The introduction of resistant varieties and biological methods offer good prospects, but their adoption remains hampered by economic and logistical obstacles. Finally, integrated disease management strategies offer a promising combined approach but require increased collaboration between local stakeholders and continued training of producers.

#### B. Effectiveness of Strategies to Control Banana Bacterial Wilt in South Kivu

The effectiveness of different strategies implemented to control banana bacterial wilt in South Kivu varies depending on several factors, including climatic, socio-economic, technical conditions, and the mobilization of local stakeholders. Although some approaches have shown positive results, their large-scale implementation faces several obstacles, including limited resources, the speed of disease spread, and pathogen resistance. The evaluation of different control strategies allows us to better understand their impact and the challenges associated with their adoption. The following table presents a summary of these different strategies.

Table 2 Presents a Summary of Different Strategies.

Strategy	Efficiency	Boundaries
<b>1. Chemical Treatments</b>	<ul style="list-style-type: none"> <li>- Temporary reduction of bacterial wilt symptoms, allowing short-term control (Karamura et al., 2018).</li> <li>- Effective for small-scale plantations.</li> </ul>	<ul style="list-style-type: none"> <li>- Cross-resistance of pathogens reducing long-term efficacy.</li> <li>- High costs and difficulty of access to products for small producers (Mugisha et al., 2019).</li> <li>- Negative environmental impact of chemicals.</li> </ul>
<b>2. Resistant Varieties</b>	<ul style="list-style-type: none"> <li>- Significant reduction in the spread of bacterial wilt, providing long-term sustainable protection (Bertsch et al., 2020).</li> <li>- Less reliance on chemical treatments.</li> </ul>	<ul style="list-style-type: none"> <li>- Low adoption due to high production costs and limited distribution of seeds.</li> <li>- Insufficient awareness among local producers of these new varieties.</li> <li>- Efficacy sometimes variable depending on the strains of the pathogen.</li> </ul>
<b>3. Biological Methods</b>	<ul style="list-style-type: none"> <li>- Significant reduction in the spread of bacterial wilt under controlled conditions (Nchinda et al., 2021).</li> <li>- Use of antagonistic microorganisms such as <i>Bacillus subtilis</i> to inhibit the pathogen.</li> </ul>	<ul style="list-style-type: none"> <li>- Results vary depending on local conditions (climate, soil type, application management).</li> <li>- Effectiveness depends on the regularity of treatments and compatibility with other agricultural practices.</li> </ul>
<b>4. Integrated Disease Management (IDM) Strategies</b>	<ul style="list-style-type: none"> <li>wilt spread through the integration of multiple approaches (crop rotation, resistant varieties, biological treatments) (Nchinda et al., 2021).</li> </ul>	<ul style="list-style-type: none"> <li>- Complexity of implementation, especially in regions with low access to resources and training.</li> <li>- Need for coordination and constant technical support.</li> <li>- Dependence on farmer adoption and awareness.</li> </ul>

Banana bacterial wilt control strategies in South Kivu reveals mixed results, with some approaches more effective than others depending on local contexts. Chemical treatments, although temporary and costly, can offer rapid disease control. Resistant varieties have long-term potential, but their adoption remains limited by economic and logistical barriers. Biological methods offer an attractive alternative, although their effectiveness varies depending on local conditions. Finally, integrated disease management appears to be a promising approach, but it requires effective coordination and ongoing farmer training to ensure its long-term success.

#### C. Actors Involved in the Management of Banana Bacterial Wilt in South Kivu

The management of banana bacterial wilt in South Kivu relies on the involvement of a plurality of actors, each playing a specific role in the fight against this devastating disease. This fight requires effective coordination between local, national and international actors to successfully control the spread of the disease while supporting vulnerable farming communities. The key actors involved in this management are presented in the table below.

Table 3 The Key Actors Involved in this Management

Actors	Role	Boundaries
<b>1. Local Farmers</b>	<ul style="list-style-type: none"> <li>- Implementation of control strategies (chemical treatments, adoption of resistant varieties, experimentation of biological methods).</li> <li>- Key players in disease management in the field.</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of financial resources and access to plant protection products.</li> <li>- Limited education and awareness on disease management ( Mugisha et al., 2019).</li> <li>- Difficulty in adopting modern control practices.</li> </ul>
<b>2. Research Institutions and Universities</b>	<ul style="list-style-type: none"> <li>- Development of resistant varieties.</li> <li>- Research on organic methods and sustainable agricultural practices.</li> <li>- Training of farmers and dissemination of research results ( Bertsch et al., 2020).</li> </ul>	<ul style="list-style-type: none"> <li>- Lack of funding for research and infrastructure.</li> <li>- Gap between academic research and the practical needs of farmers.</li> <li>- Limited dissemination of research results in local communities.</li> </ul>
<b>3. Non-Governmental Organizations</b>	<ul style="list-style-type: none"> <li>- Training of farmers.</li> <li>- Dissemination of good agricultural practices.</li> <li>- Distribution of equipment and financial support for the implementation of control projects ( Nchinda et al., 2021).</li> </ul>	<ul style="list-style-type: none"> <li>- Limited financial resources.</li> <li>- Insufficient coordination with local authorities.</li> <li>- Sometimes contradictions between local and international priorities, making interventions ineffective.</li> </ul>
<b>4. International Organizations</b>	<ul style="list-style-type: none"> <li>- Coordination of global efforts to combat the disease.</li> <li>- Provision of technical and financial support (FAO, CIRAD).</li> <li>- Partnerships with governments and other local actors ( Bertsch et al., 2020).</li> </ul>	<ul style="list-style-type: none"> <li>- Difficulty in coordinating with local realities.</li> <li>- Logistical challenges and governance issues in project implementation.</li> <li>- Resources do not always reach local levels effectively.</li> </ul>
<b>5. Local and National Governments</b>	<ul style="list-style-type: none"> <li>- Formulation of agricultural and phytosanitary policies.</li> <li>- Coordination of efforts to combat bacterial wilt .</li> <li>- Distribution of financial resources for local projects ( Karamura et al., 2018).</li> </ul>	<ul style="list-style-type: none"> <li>- Weak administrative capacity and lack of funding.</li> <li>- Political conflicts and local insecurities that hamper the implementation of programs.</li> <li>- Difficult governance and coordination at the local level.</li> </ul>

Actors involved in bacterial wilt management in South Kivu are varied and each makes a vital contribution to the fight against this disease. However, major challenges include the coordination of efforts between the different actors, the mobilization of resources and awareness raising among local producers. Collaboration between farmers, research institutions, NGOs, international organizations and government authorities is essential to develop sustainable solutions and improve the effectiveness of control strategies.

*D. Practical Recommendations for the Fight against Banana Bacterial Wilt in South Kivu*

Controlling banana bacterial wilt in South Kivu requires an integrated approach that is adapted to local conditions. Current strategies, although effective in some contexts, suffer from limitations due to socio-economic barriers , infrastructure issues , and difficulties in adoption by farmers. Therefore, it is crucial to propose practical recommendations that aim to strengthen efforts to control this disease while taking into account local realities, producer capacities, and available resources. Here is a summary table of recommendations to improve the management of banana bacterial wilt in South Kivu:

Table 4 recommendations to improve the management of banana bacterial wilt in South Kivu

Recommendations	Proposed Actions	Objectives Aimed at
<b>1. Strengthening Research and Development</b>	<ul style="list-style-type: none"> <li>- Invest in research on resistant varieties and organic methods.</li> <li>- Strengthen the training of local researchers in collaboration with international institutions.</li> </ul>	<ul style="list-style-type: none"> <li>- Develop solutions adapted to local conditions.</li> <li>- Ensure knowledge transfer to strengthen local capacities.</li> </ul>
<b>2. Improving Access to Resistant Varieties</b>	<ul style="list-style-type: none"> <li>- Subsidize the production of resistant seeds and strengthen distribution networks.</li> <li>- Raise awareness among farmers about the benefits of resistant varieties and create certified seed multiplication centers.</li> </ul>	<ul style="list-style-type: none"> <li>- Facilitate producers' access to resistant varieties.</li> <li>- Guarantee large-scale distribution of adapted seeds.</li> </ul>
<b>3. Optimization of the Use of Biological Methods</b>	<ul style="list-style-type: none"> <li>- Promote the use of antagonistic bacteria and organic fertilizers.</li> <li>- Train farmers in the correct application of organic methods.</li> <li>- Encourage the integration of organic methods into GIM.</li> </ul>	<ul style="list-style-type: none"> <li>- Reduce dependence on chemical treatments.</li> <li>- Promote sustainable and comprehensive disease management.</li> </ul>

<b>4. Improve Integrated Disease Management (IDM) Practices</b>	- Strengthen coordination between local actors to implement GIM strategies. - Develop local guidelines for integrated management. - Raise awareness among farmers about preventive strategies.	- Improve long-term disease management. - Ensure a more holistic and sustainable approach.
<b>5. Institutional and Financial Support</b>	- Mobilize financial resources to support fight projects. - Support microcredits for farmers. - Strengthen partnerships to ensure continued support.	- Ensure sufficient funding for control projects. - Encourage access to modern agricultural technologies for small producers.
<b>6. Monitoring and Evaluation of Control Strategies</b>	- Establish a system for monitoring strategies at different levels (local, regional, national). - Involve farmers in data collection to better understand the difficulties on the ground.	- Monitor and evaluate the effectiveness of the strategies implemented. - Adapt management policies based on the results obtained in the field.

The proposed practical recommendations aim to improve the management of banana bacterial wilt in South Kivu by increasing access to modern agricultural technologies, promoting sustainable practices, and strengthening coordination between the different actors involved in the fight against the disease. To be effective, these recommendations must be accompanied by institutional support and continuous training of farmers, while taking into account local socio-economic realities. Successful implementation of these recommendations could contribute to significantly reducing the impact of bacterial wilt and ensuring food security in the region.

#### IV. CONCLUSION

The Banana bacterial wilt, caused by *Xanthomonas campestris* pv. *musacearum*, represents a major challenge for banana production in South Kivu, threatening food security and the livelihoods of local communities. Despite control efforts, the rapid spread of the pathogen and economic and logistical constraints complicate its control. Current strategies, such as the use of resistant varieties and integrated disease management (IDM), have shown mixed but promising results. However, limited adoption of these methods by producers, due to economic factors and lack of awareness, hinders their long-term effectiveness.

To improve the fight against this disease, it is essential to strengthen coordination between local, national and international actors, while promoting a collaborative approach. The promotion of local research, the development of resistant varieties adapted to the climate of South Kivu and the integration of organic methods in IMM are avenues of solutions to explore. Public policies must support these initiatives through increased funding, continuous training of producers and the establishment of monitoring mechanisms. An inclusive and sustainable regional approach is necessary to limit the spread of the pathogen and ensure effective management of bacterial wilt in the region.

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