American Journal of Sustainable Agriculture and Rural Development (AJSARD)

VOLUME 2 ISSUE 1 (2026)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Sustainable Agriculture and Rural Development (AJSARD)
Volume 2 Issue 1, Year 2026
https://journals.e-palli.com/home/index.php/ajsard

Organic Approaches in Pest and Disease Management of Cavendish Banana in the Philippines: A Comprehensive Review

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Article Information

Received: January 26, 2026
Accepted: April 03, 2026
Published: July 21, 2026

Keywords

Biological Control, Cavendish Banana, Integrated Pest Management, Organic Production, Sustainable Agriculture

ABSTRACT

The Cavendish banana (*Musa* spp.) is a major export and staple fruit crop in the Philippines and remains important to food security, rural livelihoods, and the national economy. Its production is constrained by insect pests, nematodes, and destructive diseases, especially Black Sigatoka, Fusarium wilt including Tropical Race 4, and bacterial wilt. This review synthesizes current literature on organic and integrated pest and disease management approaches for Cavendish banana production in the Philippines across major stages of cultivation, including land preparation, nursery management, planting and crop care, fruit care, nutrient management, and disease-specific interventions. The review highlights the value of disease-free planting materials, compost and organic amendments, balanced nutrition, mulching, sanitation, crop and canopy management, and biological control agents such as *Trichoderma*, *Bacillus*, and entomopathogenic fungi. It also examines organic fruit care practices, including deflowering, defingering, biodegradable bagging, and leaf pruning. The synthesis shows that although organic systems may require greater labor and may initially produce lower yields than conventional systems, they offer long-term advantages through improved soil health, reduced chemical dependence, enhanced ecological balance, and better production resilience. Major constraints to wider adoption include variable pest pressure, inconsistent access to validated biological inputs, and limited farmer training. Overall, organic and integrated approaches provide a practical pathway toward more sustainable Cavendish banana production in the Philippines while maintaining acceptable productivity and fruit quality.

INTRODUCTION

Banana (*Musa* spp.), particularly the Cavendish cultivar, is one of the most significant fruit crops in the Philippines, serving both domestic consumption and international markets. The Philippines is among the top exporters of Cavendish bananas globally, making the sustainability of production systems economically and socially important. However, banana production is continually threatened by pests, nematodes, and fungal diseases, which can drastically reduce yield and fruit quality. Among these, the Sigatoka leaf spot complex, particularly Black Sigatoka (*Mycosphaerella fijiensis*), is the most devastating, causing premature leaf senescence, reduced photosynthetic capacity, and smaller bunches (Maxa *et al.*, 2024). Conventional management strategies often rely heavily on synthetic fungicides and insecticides. While effective, repeated chemical use raises environmental concerns, fosters pathogen resistance, and can negatively affect human health.

Organic and integrated pest and disease management (IPDM) strategies have gained attention as sustainable alternatives. These approaches aim to reduce chemical input while maintaining productivity, improving soil health, enhancing plant resistance, and protecting ecological balance. Organic management involves the strategic use of cultural, biological, and organic interventions throughout the crop lifecycle. In addition to traditional organic methods, innovative digital tools like SaBaTech (Gerance *et al.*, 2025) offer promising advances in pest detection. These technologies use deep learning to identify pests and diseases in real-time, which can assist in early intervention and support organic farming practices aimed at reducing reliance on chemical control.

This review synthesizes the current knowledge on organic approaches to banana pest and disease management in the Philippines, covering all production stages: land preparation, nursery management, planting, plant and fruit care, and Black Sigatoka management. Additionally, comparative insights between conventional and organic approaches are presented to provide practical guidelines for sustainable Cavendish banana production.

LITERATURE REVIEW

Land Preparation

Successful organic banana production begins with proper land preparation. Site selection is paramount; ideally, banana plantations should be established on well-drained loamy soils with good fertility and minimal risk of waterlogging. Waterlogged soils favor root rot and nematode proliferation, which can significantly compromise plant health (Business Diary, 2023). Prior to planting, all remnants of previous banana crops pseudostems, corms, and leaf residues must be removed. Such residues can harbor pests, nematodes, and fungal spores, including those causing Black Sigatoka. Depending on local practices, residues may be composted,

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deep-buried, or carefully burned to eliminate inoculum (Organic Africa, 2023).

In organic systems, the incorporation of organic amendments is essential. Well-rotted compost, farmyard manure, or green manures enhances soil fertility, promotes microbial diversity, and improves soil structure, which collectively support plant health and pest suppression. Intercropping or cover cropping during fallow periods can suppress weed growth and reduce the build-up of soil-borne pests while improving soil organic matter. In regions prone to nematode infestations, crop rotation with non-host species before banana replanting has proven effective in reducing pest pressure. The careful integration of these land preparation practices establishes the foundation for a robust and disease-resilient banana crop.

Nursery Management

The establishment of a clean, healthy nursery is critical in organic banana production. Disease-free planting materials—either tissue-cultured plantlets or selected suckers from healthy mother plants—are the first line of defense against viral, fungal, and nematode pathogens (Business Diary, 2023). Tissue culture ensures uniformity, free of pathogens, and allows rapid multiplication of elite cultivars.

Nursery substrates must be sterilized or pathogen-free to prevent early contamination. Additionally, pre-plant treatments such as hot-water immersion of corms (typically 45–50°C for a defined duration) can reduce nematode infestation and fungal spores (Kau, 2023). Nursery hygiene, including sanitation of containers, benches, tools, and water, is critical. Preventing movement of soil and tools between infested and clean areas reduces cross-contamination. The integration of beneficial microbes into the nursery, such as *Trichoderma* spp., may enhance early plant defense, promoting healthier seedlings ready for field transplantation.

Planting and Plant Care Operations

Field establishment and early plant care are crucial to sustaining plant vigor and reducing susceptibility to pests and diseases. Plant spacing of approximately 2.5 m × 2.5 m is recommended to enhance air circulation and decrease leaf wetness, limiting fungal infection and Sigatoka spread (Business Diary, 2023). Mulching with organic materials, such as rice straw or dried leaves, conserves soil moisture, suppresses weeds, and fosters a favorable microclimate for beneficial soil microorganisms (Cultivation AG, 2023).

Organic fertilization, using compost, vermicompost, or fermented organic fertilizers, supplies essential nutrients while promoting soil microbial diversity. Excessive nitrogen, common in conventional fertilization, can exacerbate fungal diseases, highlighting the importance of balanced organic nutrition. Biological control agents, including entomopathogenic fungi (*Beauveria bassiana*, *Metarhizium anisopliae*) and nematodes, suppress pests such as banana weevils and nematodes. Regular pruning of dead or diseased leaves, removal of old pseudostems after harvest, and sanitation of the field reduce pest hiding places and inoculum sources for fungal pathogens (Kau, 2023).

Routine monitoring and field scouting enable early detection of pest and disease outbreaks. Integrated organic practices combine these preventive and curative measures to maintain plant health and optimize productivity.

Fruit Care Operations

Fruit quality is closely linked to plant health and consistent management. Minimizing mechanical injury during harvesting and transport is crucial because wounds serve as entry points for pathogens (Pests & Diseases, 2023). Healthy, well-maintained plants produce better-quality bunches, reducing susceptibility to fruit-spot diseases. Post-harvest sanitation, including the removal and proper composting or destruction of old pseudostems and debris, prevents survival and carryover of soil-borne pests and pathogens. These practices complement pre-harvest interventions, reinforcing disease suppression and supporting sustainable organic production.

Deflowering

In Cavendish banana production in the Philippines, deflowering is practiced to remove the male bud, preventing the plant from wasting energy and thereby improving fruit quality. The organic approach involves manually removing the male bud using sterilized tools, ensuring that cuts are clean to minimize the risk of infection. After removal, a copper-based fungicide approved for organic use or a potassium bicarbonate spray is applied to the cut end to further reduce the likelihood of fungal infection. Companies in the Philippines, such as those supplying bananas for export markets, integrate deflowering into their standard crop management protocols, often combining it with practices like bagging, leaf pruning, and careful bunch handling to ensure export-quality fruit while maintaining organic and sustainable production standards.

Defingering (Removal of Extra Fingers)

This operation is carried out to reduce overcrowding, improve fruit size, and ensure uniformity of the bunch. The organic approach involves manually removing the extra fingers using clean, sharp tools, taking care to make precise cuts that do not damage the remaining fruit. Removed fingers are properly disposed of through composting or burning to prevent the spread of diseases, and care is taken not to leave them at the base of the plants to avoid attracting pests. Leading banana companies in the Philippines incorporate defingering into their regular crop management routines, alongside practices like deflowering, bagging, and leaf pruning, to produce high-quality fruit suitable for both local and export markets while adhering to organic and sustainable production standards.

Bagging of Bunches

A common practice aimed at protecting fruits from pests such as thrips and weevils, as well as from birds, wind damage, sunburn, and fungal spores. Organic approaches are increasingly being adopted, with farmers using biodegradable paper or cloth bags instead of conventional plastic or chemically treated bags. Some growers also utilize recycled newspapers or jute/cloth sleeves, often treating them with neem oil or other botanical repellents to enhance pest deterrence. Bagging is typically performed when the first hands of the bunch start to form, ensuring that the bags are loosely fitted to prevent mechanical damage while allowing adequate airflow. Companies in the Philippines, such as those operating large Cavendish plantations, integrate this practice into their standard fruit care operations, combining bagging with other measures like leaf pruning and careful monitoring to maintain fruit quality for both domestic and export markets.

Removal of Fruit Obstacles

The removal of fruit obstacles is an essential practice in organic Cavendish banana production, aimed at ensuring straight, uniform fingers and preventing fruit malformation caused by crowding or physical obstructions. This involves the careful, manual removal of leaves, suckers, or any plant parts that interfere with the proper development of the bunch. By clearing these obstacles, farmers allow the fruits to grow freely with adequate space and ventilation. In keeping with organic principles, all removed plant materials are not discarded but instead composted or incorporated into organic mulch, promoting nutrient recycling and soil health while maintaining a clean and productive growing environment.

Leaf Pruning / Deleafing

Is practiced in organic Cavendish banana production to improve sunlight penetration, reduce disease pressure, and enhance ventilation around the developing bunch. The organic approach emphasizes removing only old, dead, or heavily infected leaves to maintain plant vigor while preventing unnecessary stress caused by excessive pruning. Careful selection of leaves ensures that the plant retains enough healthy foliage for optimal photosynthesis and growth. Additionally, pruning tools should be disinfected between plants using 70% ethanol or an organic-approved sanitizer to minimize the risk of spreading pathogens, thereby supporting a healthier and more resilient plantation.

Nutrient Management for Quality Fruits

Plays a vital role in supporting organic bunch treatments and ensuring high-grade Cavendish banana production. The organic approach centers on enhancing the plant's nutritional status through natural, bio-based inputs that promote fruit size, skin quality, and overall plant resilience. Foliar applications of seaweed extracts, fish emulsion, compost tea, or vermicompost extracts provide readily absorbable nutrients and beneficial microorganisms that boost physiological processes and strengthen the plant against environmental stress. These organic amendments not only improve the appearance and quality of the fruits but also contribute to healthier, more sustainable soil and crop systems.

Organic Pest and Disease Prevention in Bunches

This focuses on minimizing pests such as thrips and aphids, as well as diseases like Sigatoka, without relying on chemical inputs. This approach integrates botanical sprays—such as neem oil, garlic-chili extracts, and essential oil mixtures—that act as natural repellents or disrupt pest development. Biological control agents also play a key role, with the release of predatory insects like lady beetles or the application of entomopathogenic fungi such as *Beauveria bassiana* near inflorescences to naturally suppress pest populations. Additionally, maintaining organic mulch and proper ground management fosters beneficial soil organisms that contribute to overall plant health and indirectly reduce pest pressure, creating a balanced and resilient production environment.

Nutrient Management / Fertilization

Common fertilizers used in Cavendish banana plantations in the Philippines include a range of macronutrient, secondary nutrient, and micronutrient sources that support the crop's high nutritional demand. Nitrogen is typically supplied through urea, ammonium sulfate, ammonium nitrate, or NPK compound blends because it drives vigorous vegetative growth, leaf expansion, and overall yield; plantations often apply N in split doses to reduce leaching losses. Phosphorus, usually provided as triple superphosphate (TSP) or mono-ammonium phosphate (MAP), is essential for strong root development, early plant establishment, and energy-related processes during flower and bunch initiation. Potassium is most commonly applied as muriate of potash (MOP) and sometimes as sulfate of potash (SOP) is considered the most critical nutrient for Cavendish, influencing fruit size, sweetness, assimilate transport, and tolerance to stress and disease, with deficiencies directly reducing bunch weight. Secondary nutrients such as calcium and magnesium are added through gypsum, lime, kieserite, or Epsom salts when soil tests indicate a need, while micronutrients like boron, zinc, manganese, and copper are supplied either through compound fertilizers or foliar sprays to ensure proper bunch formation, fruit quality, and disease resilience. Many Philippine plantations also use specialized products such as banana-specific NPK blends (e.g., 15-15-15, 12-12-17, 15-15-6) for maintenance fertilization, as well as nursery-enhancing products like single-dose controlled-release fertilizers and foliar supplements to improve tissue-cultured seedling vigor.

Soil and leaf analysis first (diagnostic step)

Commercial plantations and most research-based recommendations start from soil and leaf tissue analysis to determine existing nutrient status and set fertilizer

rates. Soil tests guide P and K and pH amendments; leaf (foliar) analysis is used to monitor plant nutrient uptake and to fine-tune ongoing applications.

Design of a crop nutrition program (balanced N-P-K + secondary & micros)

Programs are made for the production cycle and include: basal (establishment) rates, regular maintenance/ top dressings during vegetative growth, and specific applications during bunch initiation and fruit filling. Large growers adapt the rates per soil/leaf results and adopt blanket N-P-K targets per bunch or per hectare. International fertilizer companies (e.g., Yara, Haifa) publish sample Cavendish programs commonly used as references.

Types of applications and timing

i. Basal / banding / ring application of granular fertilizers around the mat/plant at planting and early growth.

ii. Split applications / top-dressing of nitrogen (and sometimes potassium) at regular intervals (every 6–8 weeks or timed to growth stages) to match plant demand and reduce losses.

iii. Foliar sprays for fast correction of micronutrient deficiencies (Zn, B, Mn) and for supplemental feeding during critical stages. Foliar sprays may include Cu if fungicide use is limited.

iv. Fertigation in irrigated blocks (through drip or micro-sprinkler) is used by some modern plantations to supply soluble fertilizers more precisely.

v. Organic amendments (compost, manure, green manure) are used in combination with mineral fertilizers where available to improve soil organic matter and structure.

Monitoring & adjustment

Routine leaf sampling and monitoring (and yield/bunch weight data) are used to adjust rates year to year. Studies show correlation between soil/leaf nutrient levels, applied fertilizer, and bunch weight — plantations therefore adapt fertilization regimes based on measured responses. Large Cavendish banana plantations in the Philippines implement fertilization using structured, science-based programs supported by soil and leaf diagnostics, company protocols, and agronomist-recommended nutrient guides. A study at Lapanday Foods Corporation's Farming Town Plantation Operations (FPO) demonstrated how soil and leaf analysis results were used as the primary basis for fertilizer planning, with researchers noting that naturally high soil levels of potassium, calcium, and magnesium significantly influenced nutrient scheduling and ultimately affected bunch weight (Salibay, 2009; Lapanday FPO, Philippine EJournals).

Major exporters and multinational companies follow standardized banana nutrition protocols developed by their mother companies, as documented in the Department of Agriculture's Philippine Banana Industry Roadmap (2021–2025). These corporations use tissue-cultured planting materials, apply uniform NPK and micronutrient schedules, and employ plantation agronomy teams to ensure consistent nutrient management aligned with Good Agricultural Practices (GAP). In addition, private-sector agronomists and fertilizer companies like Yara Philippines and Haifa Group publish Cavendish banana nutrition programs that many commercial growers adopt or adapt, providing guidelines on NPK requirements, micronutrient correction, and foliar supplementation. Proper fertilization in these large operations is essential because balanced NPK particularly sufficient potassium improves bunch weight and overall yield, enhances fruit size and export quality, strengthens plant vigor and disease tolerance, and increases cost efficiency by minimizing nutrient losses through split applications and diagnostic-based programs (Transactions on Science and Technology; Haifa Group; Philippine EJournals).

Pest and Disease Management

Commercial Cavendish plantations in the Philippines use an Integrated Pest/Disease Management (IPM) approach that combines prevention & biosecurity, regular scouting & monitoring, cultural controls, chemical control (carefully scheduled sprays), biological/softer methods where possible, and supply-chain measures (use of disease-free planting material, certification, and grower agreements). Large exporters and plantation groups operate centralized agronomy teams and follow written spray calendars and biosecurity SOPs to meet export standards.

Prevention & biosecurity (first line of defense)

Prevention and biosecurity serve as the first line of defense in Cavendish banana production, aiming to minimize the introduction and spread of pathogens. A key strategy is the use of disease-free planting material, such as tissue-cultured or certified plantlets. Commercial plantations routinely source tissue-cultured Cavendish plantlets to avoid seedborne or planting material–borne pathogens, which is particularly important for limiting Banana Bunchy Top Virus (BBTV) and other diseases. Research from Bioversity/CGIAR and Philippine trials highlights the importance of using clean planting material and tolerant somaclones to enhance disease resilience. Complementing this, strict quarantine and movement controls, along with rigorous disinfection protocols for soil, plant material, vehicles, boots, and dedicated machinery, are implemented, especially in areas at risk of *Fusarium oxysporum* f. sp. *cubense* TR4 (Foc-TR4). Zoning strategies further reinforce containment, as documented in ACIAR and industry reports on Mindanao plantations. These measures are critical because soil-borne pathogens like TR4 are extremely difficult to eradicate once established, making prevention far more effective than attempting post-infection cures.

Recent technological advancements in pest and disease management, such as SaBaTech (Gerance *et al.*, 2025), offer

real-time, web-based applications to detect banana pests and diseases, aligning with organic farming's emphasis on early detection and sustainable pest management.

Scouting, monitoring & decision thresholds

Scouting, monitoring, and the use of decision thresholds are essential components of integrated pest and disease management in Cavendish banana plantations. Routine field scouting, conducted weekly or biweekly in high-value export blocks, focuses on the early detection of pests and diseases such as Black Sigatoka (characterized by leaf spots), thrips, weevils, nematodes, and insect vectors like aphids that transmit BBTV. Plantations maintain detailed disease incidence records and spray calendars at the block level, tracking fungicide use, number of sprays, and observed disease levels. These records help managers implement timely fungicide rotations and minimize the development of resistance. The Department of Agriculture's Roadmap and production manuals emphasize the importance of monitoring to schedule applications effectively, such as timing sprays for Black Sigatoka. Timely detection through scouting reduces the pathogen inoculum, enabling targeted treatments rather than blanket applications, which lowers production costs and mitigates the risk of resistance.

Cultural controls and sanitation

Cultural controls and sanitation play a vital role in managing pests and diseases in Cavendish banana plantations. Common practices include pruning and rogueing infected leaves to reduce Black Sigatoka inoculum, as well as sanitizing harvest wounds, promptly removing diseased mats, and destroying volunteer plants to limit the spread of BBTV and fungal pathogens. Field design measures, such as proper layout, drainage, and windbreaks, help reduce spore dispersal and minimize physical damage to plants. Where feasible, crop rotation or fallowing is implemented, and less susceptible somaclonal lines, such as GCTCV selections, are trialed to enhance disease resilience. These cultural practices are critical because they reduce the overall pathogen load and, when combined with chemical control measures, provide more durable and sustainable disease management.

Chemical control — fungicides, insecticides, nematicides

Chemical control through fungicides, insecticides, and nematicides remains a key component of integrated pest and disease management in commercial Cavendish banana plantations. For Black Sigatoka (caused by *Mycosphaerella/ Paracercospora* spp.), frequent fungicide applications form the backbone of control, applied via ground or aerial spraying where permitted. Fungicide classes commonly used include triazoles, QoIs (strobilurins), multi-site protectants such as mancozeb, SDHIs, and newer mixtures, with plantation protocols emphasizing rotation of modes of action to delay resistance. Major crop protection companies, including BASF and Syngenta, supply products tailored for banana Sigatoka management, and the Department of Agriculture's roadmap notes frequent aerial and ground sprays in export blocks. In contrast, Fusarium wilt caused by TR4 (*Fusarium oxysporum* f. sp. *cubense*) has no reliable chemical cure once soil is infected. Management focuses on prevention, containment, and planting tolerant lines, with chemical soil amendments or fungicidal products providing, at best, mitigation rather than eradication, as emphasized by ACIAR, PRO*Musa*, and scientific reviews. Insect pests such as thrips, banana weevils, aphids, and caterpillars are managed with insecticides and biorational products, including newer selective chemistries like pyridalyl or matrine, often integrated with biological control agents and trapping strategies. Nematode management relies on nematicides combined with cultural practices such as root sanitation, fallowing, and organic amendments as part of integrated block rehabilitation. These chemical controls are crucial for immediate protection of export-quality fruit from foliar diseases like Sigatoka but must be carefully integrated with monitoring, cultural practices, and rotation schemes to minimize resistance and environmental impact, while recognizing that for TR4, biosecurity and tolerant germplasm remain the central strategies.

Biologicals, environmental & reduced-risk options

Biologicals, environmental, and reduced-risk options are increasingly integrated into Cavendish banana pest and disease management to complement chemical control and reduce environmental impact. Biological fungicides, biorational products, biodegradable crop oils, and biocontrol agents are used in some commercial plantations as well as by smallholder growers to lower chemical inputs. In the Philippines, growers have trialed and, in some areas, adopted these environmentally friendly alternatives, supported by FAO and local extension programs that promote integrated pesticide management and safer control methods. These approaches are important because they reduce chemical exposure, enhance worker safety, and contribute to resistance management, making them a valuable component of sustainable banana production. In the Philippines, Cavendish banana plantations implement a range of agronomic and disease management practices tailored for both productivity and export standards. Lapanday Foods Corporation, often cited in Philippine case studies and Bioversity/CGIAR reports, exemplifies this approach through trials and adoption of TR4-tolerant somaclones (GCTCV lines) and diagnostic-based fertilization and pest management; they have also been actively involved in national TR4 response programs. Similarly, multinational exporters operate large-scale integrated nutrition and crop protection programs, supported by centralized agronomy teams and strict adherence to Good Agricultural Practices (GAP) and certification standards, as documented in the DA Banana Industry Roadmap. More broadly, the Philippine banana industry follows nationally recommended

practices summarized in the DA Roadmap and HVCDP Production Manual, including frequent fungicide applications for Sigatoka control in Cavendish export blocks, combined with cultural sanitation measures and regular field monitoring to maintain plant health and fruit quality.

Black Sigatoka Management

Black Sigatoka remains the most significant leaf disease affecting Cavendish banana. In organic production, integrated strategies focus on cultural, biological, and preventive measures. Cultural practices include selecting well-drained sites with full sun exposure and optimizing plantation design to improve airflow and reduce leaf wetness periods (LucidCentral, 2023). Plant spacing and row orientation relative to prevailing winds further limit fungal spore germination. Regular removal of infected leaves reduces inoculum load, while maintaining weed-free conditions prevents microenvironments favorable to fungal development.

Biological interventions involve applying beneficial microorganisms such as *Bacillus subtilis*, *Pseudomonas fluorescens*, and *Trichoderma* spp., which enhance plant defenses and suppress pathogen growth (Kau, 2023). Organic sprays, including botanical extracts (e.g., neem, garlic, citrus seed), mineral oils, and compost teas, serve as preventive and curative treatments. Routine monitoring through scouting allows early intervention, improving the effectiveness of integrated organic measures. Collectively, these practices reduce Black Sigatoka incidence without relying on synthetic fungicides (Maxa *et al.*, 2024; Agric4Profits, 2023).

Fusarium and Bacterial Wilt Management in Cavendish Banana

Cavendish banana production in the Philippines faces significant challenges from soil-borne and bacterial pathogens, particularly *Fusarium oxysporum* f. sp. *cubense* (Foc), which causes Fusarium wilt (including the Tropical Race 4 strain, TR4), and *Ralstonia solanacearum*, the causal agent of bacterial wilt. These diseases lead to wilting, stunted growth, yellowing of leaves, and ultimately plant death, posing severe threats to export-quality bananas. Conventional chemical controls are limited in effectiveness against these pathogens, making organic and integrated approaches essential for sustainable management.

Use of Organic Amendments and Soil Health Management

Maintaining healthy soil is a primary defense against Fusarium and bacterial wilt in Cavendish banana cultivation. Organic approaches focus on improving soil health and enhancing the natural suppression of pathogens. Incorporating well-decomposed compost, farmyard manure, and green manures improves soil structure, increases microbial diversity, and encourages populations of antagonistic microbes that inhibit pathogen activity. The use of biofertilizers containing beneficial microorganisms such as *Trichoderma* spp., *Bacillus* spp., and mycorrhizal fungi, applied to soil or seedlings, not only enhances nutrient uptake but also induces systemic resistance against infections. Additionally, implementing crop rotation with non-host crops and intercropping with legumes helps reduce the build-up of pathogens in the soil while further enriching soil fertility, creating a more resilient growing environment for bananas.

Biological Control

Biological control is an important strategy for managing soil-borne pathogens in Cavendish banana cultivation. Fungi such as *Trichoderma* spp. act as strong antagonists against Fusarium by colonizing the rhizosphere and producing antifungal compounds that inhibit pathogen growth. Beneficial bacteria, including *Bacillus subtilis* and *Bacillus amyloliquefaciens*, suppress both *Fusarium* and *Ralstonia* through antibiotic production and the induction of plant defense mechanisms. Similarly, *Pseudomonas fluorescens*, when applied as a soil drench or root dip, can reduce disease incidence while enhancing overall plant vigor, providing an eco-friendly alternative to chemical controls.

Among biological control agents, *Bacillus subtilis* and *Pseudomonas fluorescens* have shown significant promise in managing Fusarium wilt (Figueroa & Hagonos Jr., 2022). These beneficial microorganisms not only reduce pathogen growth but also enhance plant defenses, aligning with organic practices that reduce chemical dependence. For managing Fusarium wilt (including TR4), biological products such as *Bacillus subtilis* have demonstrated antifungal activity (Figueroa & Hagonos Jr., 2022). Integrating these products into organic systems offers an eco-friendly alternative to synthetic fungicides.

Seedling and Plant Sanitation

Seedling and plant sanitation is a critical component of organic management of Fusarium and bacterial wilt in bananas. Using clean, disease-free planting material, such as tissue-cultured seedlings from certified nurseries, ensures plants are free from Fusarium and bacterial contamination. Before transplanting, banana suckers can be treated with root dips containing beneficial microbes to establish protective rhizosphere communities. Maintaining strict field hygiene, including the regular removal of infected plants, sterilization of tools, and minimizing the movement of soil and water from infected areas, further reduces the risk of disease spread and supports the establishment of healthy, resilient banana plantations.

Cultural and Physical Practices

Cultural and physical practices play a vital role in preventing Fusarium and bacterial wilt in banana cultivation. Improving soil drainage through raised beds or well-drained planting mounds helps reduce the risk of infection, as these pathogens thrive in waterlogged

soils. The use of organic mulches minimizes soil splash, creating a protective barrier that prevents soil-borne pathogens from reaching the plant base. Additionally, cover cropping with legumes or grasses supports populations of beneficial soil microbes that compete with pathogens, enhancing soil health and further reducing disease pressure in the plantation.

Integrated Organic Management

Integrated organic management offers the most effective approach to controlling Fusarium and bacterial wilt in banana cultivation by combining multiple organic practices with careful monitoring. Regular scouting for early disease symptoms allows for timely intervention, while the combined application of biological agents and organic amendments strengthens plant resistance and soil health. Avoiding monoculture plantations and maintaining proper sanitation further minimize disease spread. This holistic approach has been promoted in Philippine banana plantations and smallholder farms, demonstrating its effectiveness in reducing disease incidence while enhancing soil fertility, sustainability, and long-term plantation resilience.

Comparative Analysis: Organic vs Conventional Approaches

A comparative assessment of conventional and organic approaches highlights key differences and trade-offs in banana production (Table 1). Conventional systems rely on synthetic fertilizers, pesticides, and fungicides, offering rapid pest suppression and high short-term yields but posing environmental and health risks. Organic systems emphasize soil health, biodiversity, and ecological balance, using compost, biological control, and cultural interventions to manage pests and diseases. While organic yields may initially be lower, long-term sustainability, improved soil resilience, and reduced chemical dependence make organic approaches attractive for smallholder farms and environmentally conscious production.

Table 1: Comparative Summary of Conventional vs Organic Approaches in Cavendish Banana Production

Aspect	Conventional	Organic/Integrated
Fertilization	Synthetic NPK, rapid effect	Compost, vermicompost, green manure
Pest Control	Chemical pesticides	Biological control, cultural practices
Disease Control	Synthetic fungicides	Biofungicides, botanical extracts, sanitation
Soil Health	Risk of degradation	Enhanced microbial diversity, organic matter increase
Environmental Impact	High	Low
Sustainability	Short-term productivity	Long-term resilience

Challenges and Research Gaps

Despite the benefits, organic banana production in the Philippines faces challenges. Variability in pest and disease pressure, smallholder farm constraints, and labor-intensive management practices can limit adoption. Research gaps include validation of local biological control agents, optimization of organic amendments for different soil types, and development of epidemiological models to predict Sigatoka outbreaks under changing climatic conditions. Training programs and extension services are essential to equip farmers with the knowledge and skills required for successful organic production (Maxa *et al.*, 2024; Kau, 2023).

MATERIALS AND METHODS

This review was conducted by synthesizing information from primary research studies, agricultural extension materials, and case reports relevant to organic banana farming in the Philippines. Data were selected from multiple sources as indicated in the references, including government reports, academic journal articles, and industry guidelines. The focus was on integrated pest management (IPM), biological control agents, organic fertilization techniques, and disease-specific management strategies for Black Sigatoka and Fusarium wilt.

The studies were filtered based on their relevance to organic farming practices and their geographic focus on banana production in the Philippines. Only peer-reviewed academic articles, credible government reports, and case studies were considered, ensuring the reliability and validity of the included data. Comparative analyses between organic and conventional management practices were also integrated, which included studies on the effectiveness of various organic interventions in managing banana pests and diseases.

All data were analyzed through a thematic synthesis approach, categorizing findings into key management strategies, such as biological control, organic fertilization, and pest/disease control practices. Studies addressing long-term sustainability, ecological impact, and yield performance were emphasized to provide a comprehensive overview of the benefits and challenges of organic banana farming in the Philippines.

RESULTS AND DISCUSSION

Land Preparation and Nursery Management

Organic banana production begins with comprehensive land preparation, including soil enhancement through compost, farmyard manure, and green manures. Proper sanitation is critical, including the removal of previous crop residues to prevent the spread of pests and diseases. The use of disease-free planting material is emphasized, with tissue-cultured plantlets being the preferred method to reduce pathogen introduction.

Planting and Plant Care

Organic planting techniques recommend specific plant spacing to improve air circulation and reduce leaf wetness, thereby minimizing fungal infections like Black Sigatoka. Mulching is commonly used to retain soil moisture and suppress weed growth. Organic fertilization through compost and vermicompost promotes microbial diversity and enhances soil health. Biological control agents such as *Trichoderma* and *Beauveria bassiana* are applied to control pests like banana weevils and nematodes.

Fruit Care and Protection

Organic fruit protection includes deflowering, defingering, and biodegradable bagging. These practices, combined with leaf pruning and careful handling, aim to reduce pest infestations and enhance fruit quality. The use of organic pesticides and natural repellents like neem oil further protects fruits from common pests like thrips and aphids.

Comparative Analysis of Conventional vs. Organic Systems

Organic systems tend to have higher labor inputs and initially lower yields compared to conventional systems. However, they offer long-term advantages, such as improved soil health, reduced chemical usage, and greater resilience to pests and diseases. Conventional systems, in contrast, often rely heavily on chemical inputs for immediate pest suppression but may lead to soil degradation and higher environmental risks in the long term.

Synthesis and Implications

The review highlights that organic and integrated pest management systems, while requiring more intensive labor and initial investment, offer several long-term benefits, including improved soil fertility, reduced chemical dependence, and enhanced biodiversity. Organic approaches, such as the use of composts, mulching, biological control agents, and the careful management of fruit care, contribute to a more resilient and sustainable banana farming system. However, the adoption of these practices faces challenges, including inconsistent pest pressure, limited availability of organic inputs, and the need for greater farmer education and training.

The comparative analysis indicates that while conventional farming methods may offer quicker returns through higher short-term yields, organic systems promote greater sustainability and environmental responsibility. The integration of organic and conventional practices into a hybrid approach may provide the best solution, allowing farmers to balance productivity with ecological stewardship.

Nutrient Management for Quality Fruits

Organic fertilization is a key component of sustainable banana production, particularly for maintaining soil health and enhancing plant resistance to diseases. The use of compost, vermicompost, and fermented organic fertilizers supplies essential nutrients while promoting microbial diversity. Bestes and Olguera (2024) assessed the use of all-in-one fertilizers and foliar sprays for nutrient management in Cavendish banana seedlings, highlighting the importance of balanced fertilization for promoting seedling health and improving resistance to fungal pathogens. Their findings underscore the critical role of proper nutrient management in establishing strong, resilient plants.

Salibay and Salomez (2009) conducted an evaluation of soil and leaf analysis to guide fertilization practices in banana plantations. Their study focused on optimizing fertilizer application based on soil nutrient levels, ensuring that bananas receive the necessary nutrients at each stage of growth. They recommended a tailored fertilization approach, based on diagnostic tests, to improve nutrient uptake and fruit quality, supporting the use of nutrient management programs that are adjusted based on soil and leaf test results.

CONCLUSION

Organic and integrated pest and disease management approaches offer a sustainable and resilient alternative to conventional Cavendish banana production systems in the Philippines. This review demonstrates that effective pest and disease control can be achieved through a holistic strategy that integrates proper land preparation, clean and well-managed nurseries, balanced organic nutrient management, cultural and sanitation practices, and the strategic use of biological control agents. These practices collectively reduce reliance on synthetic agrochemicals while enhancing soil health, plant vigor, and ecological balance.

The management of major constraints such as Black Sigatoka, Fusarium wilt (including TR4), and bacterial wilt requires preventive, system-based interventions rather than curative solutions alone. Organic practices—such as improved drainage, optimized plant spacing, regular deleafing, use of composts and biofertilizers, and application of beneficial microorganisms—play a critical role in suppressing pathogen pressure and strengthening plant defense mechanisms. Similarly, organic fruit care operations, including deflowering, defingering, biodegradable bagging, and nutrient-enriching foliar applications, contribute to improved fruit quality while maintaining compliance with sustainable and export-

oriented production standards.

While conventional systems remain dominant in large-scale plantations due to their immediate efficacy and yield stability, organic and integrated systems provide clear long-term advantages, including improved soil resilience, reduced environmental impact, enhanced worker safety, and better alignment with Good Agricultural Practices (GAP) and sustainability certifications. Nonetheless, challenges such as higher labor requirements, inconsistent performance of biological inputs, and limited farmer access to technical knowledge continue to constrain wider adoption.

Addressing these challenges will require sustained research on locally adapted biological control agents, optimization of organic amendments for diverse agroecological conditions, and strengthened extension and training programs. With continued institutional support and science-based innovation, organic and integrated approaches can significantly contribute to the long-term sustainability, competitiveness, and resilience of the Philippine Cavendish banana industry.

REFERENCES

Agric4Profits. (2023). *Sustainable pest and disease control strategies for banana plantations*. https://agric4profits.com/groups/plantainbanana-*Musa*-paradisiaca-farmers-community/forum/topic/sustainable-pest-and-disease-control-strategies-for-banana-plantations/

BASF Crop Protection Philippines. (n.d.). *Solutions for Banana* (product examples used internationally and, in the Philippines, including fungicide brands for Sigatoka control). https://crop-protection.basf.ph

Bestes, J. A., & Olguera, D. T. (2024). Assessment of all-in-one fertilizers and foliar spray for nutrient management of GCTCV-218 Cavendish banana seedlings. *Southeastern Philippines Journal of Research and Development, 29*(1), 113–125. https://doi.org/10.53899/spjrd.v29i1.378

Bioversity/Alliance. (2016). *Tackling banana disease in the Philippines* — On TR4 & *local research efforts*. Bioversity/CIAT.

Business Diary. (2023). *Banana farming in the Philippines: High yield techniques for maximum profitability*. https://businessdiary.com.ph/33293/banana-farming-in-the-philippines-high-yield-techniques-for-maximum-profitability

Cultivation AG. (2023). *Organic banana farming practices*. https://cultivationag.com/organic-banana-farming/

Department of Agriculture. (2021). *Philippine banana industry roadmap* (2021–2025). DA. Agriculture Portal.

Esguera, J. G., Balendres, M. A., & Paguntalan, D. P. (2024). Overview of the Sigatoka leaf spot complex in banana and its current management. *Tropical Plants, 3,* e002. https://doi.org/10.48130/tp-0024-0001

FAO. (n.d.). Pesticide management in the banana industry / World Banana Forum (guidance on pesticide use, IPM, and safer alternatives). FAO. https://www.fao.org

Figueroa, M. A. G., & Hagonos Jr., A. S. (2022). Antifungal Effects of Different Commercial Products Against *Fusarium oxysporum* f. sp. *cubense* TR4 Causing Fusarium Wilt of Banana. *American Journal of Experimental Agriculture, 1*(2). https://doi.org/10.54536/ajec.v1i2.207

Gerance, M. D., Sta Rufina, K., Fabito, J., & Magnaye, N. (2025). SaBaTech: A Banana Fruit Pest and Disease Detection Web Application. American Journal of Data Science and Artificial Intelligence, 1(1). https://doi.org/10.54536/ajdsai.v1i1.4890

Haifa Group. (n.d.). *Crop guide: Banana fertilizer recommendations* (practical foliar & micro recommendations used internationally and adapted locally).

HVCDP / Department of Agriculture. (n.d.). *Banana production manual* (High Value Crops Development Program). High Value Crops Program.

Kau University. (2023). Organic production of banana. https://kau.edu/sites/default/files/documents/organic_production_of_banana.pdf

LucidCentral. (2023). *Banana Black Sigatoka: Cultural and sanitation management.* https://apps.lucidcentral.org/pppw_v10/text/web_full/entities/banana_black_sigatoka_002.htm

Montiflor, M. O., Vellema, S., & Digal, L. N. (2019). Coordination as management response to the spread of a global plant disease: A case study in a major Philippine banana production area. *Frontiers in Plant Science, 10*, 1048. https://doi.org/10.3389/fpls.2019.01048

Organic Africa. (2023). *Improving management of banana pests and diseases using organic approaches*. https://www.organic-africa.net/organic-agriculture/organic-agriculture/crop-management/banana-/-plantain/improving-management-of-banana-pest-and-diseases.html

Pattison, R., *et al.* (2020). *Integrated management of Fusarium wilt of bananas in the Asia-Pacific — practical containment and management recommendations; discusses limitations of chemical control for TR4*. ACIAR.

Pests & Diseases. (2023). *Black Sigatoka in bananas: Organic and chemical treatments for effective disease control.* https://pestsdiseases.com/banana-sigatoka-disease-management-symptoms-treatment-chemical-biological-and-organic-control

Salibay, M. A. L., & Salomez, J. A. (2009). Banana fertilization at the plantation: Evaluation of soil and leaf analysis results. *Southeastern Philippines Journal of Research and Development, 18*(2). https://ejournals.ph/article.php?id=9061

Yara Philippines. (n.d.). Banana — Crop nutrition solution for banana (Cavendish & Lakatan). *Yara Fertilizers Philippines Inc.*

University / research & extension materials. (n.d.). *Banana production manual — High Value Crops Development Program* (HVCDP), DA. High Value Crops Program.