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AI-DRIVEN SURVEILLANCE & PRECISION CONTROL OF CURVULARIA LUNATA A RESNET-BASED APPROACH FOR SUSTAINABLE MUSKMELON HEALTH

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Abstract
Muskmelon (Cucumis melo), a widely cultivated fruit crop, is highly susceptible to fungal pathogens that affect its leaves, stems, roots, flowers, seeds, and fruits, leading to considerable economic losses. Among these pathogens, Curvularia lunata is a primary threat, responsible for leaf blight, fruit rot, root decay, seedling damping-off, and flower necrosis, ultimately reducing crop viability and market quality. Traditional disease detection methods rely on visual inspections and conventional diagnostics, which are time-consuming, prone to errors, and often delay critical interventions. To overcome these limitations, this study integrates AI-powered surveillance using the ResNet deep learning algorithm, which processes high-resolution imagery from UAVs, spectral sensors, and in-field cameras to classify disease severity with high accuracy and precision at different plant growth stages.By leveraging pre-defined datasets and real-time monitoring, the ResNet model facilitates early detection of disease symptoms across multiple plant parts, enabling data-driven decision-making for targeted interventions. The model's performance was validated using key statistical methods, including ANOVA, paired t-tests, and regression analysis, which demonstrated a significant correlation between AI-assisted disease detection and optimized disease management strategies. Implementing AI-driven precision fungicide application schedules significantly reduced disease progression and enhanced overall plant health. The study underscores the transformative role of AI in sustainable disease management, ensuring reduced fungicide dependency, optimized resource allocation, and increased muskmelon yield. This approach also establishes a foundation for broader applications in the Cucurbitaceae family, advancing precision agriculture and eco-friendly crop protection strategies.

Keywords: AI disease detection, Curvularia lunata, ResNet, precision fungicide, sustainable farming, pest management, deep learning.

1. Introduction

Agricultural advancements have transformed farming practices, yet the growing reliance on chemical growth enhancers and synthetic pesticides has introduced significant challenges. While these chemical agents temporarily boost production, they simultaneously weaken plant immunity, making crops more vulnerable to aggressive pathogens. This phenomenon is particularly evident in muskmelon a commercially valuable member of the Cucurbitaceae family. Due to its high water content, delicate rind, and sensitivity to environmental changes, muskmelon is highly prone to fungal, bacterial, and viral infections. Among the most destructive pathogens,Curvularia lunata has emerged as a critical concern, affecting not only leaves but also stems, flowers, roots, seeds, and fruits, leading to substantial yield loss and deteriorated fruit quality [1]. In addition to Curvularia lunata, disease muskmelon crops face threats from other prevalent diseases such as powdery mildew, downy mildew, bacterial wilt, and the anthracnose. These diseases are collectively contribute to fruit rot, leaf necrosis, and premature plant decline, making muskmelon cultivation increasingly challenging. The widespread use of indiscriminate chemical treatments has further exacerbated the situation, leading to pesticide resistance, soil degradation, and harmful residues in harvested fruits in muskmelon. Moreover, climate change and fluctuating humidity levels have intensified pathogen spread, resulting in unpredictable disease outbreaks that traditional farming practices struggle to manage effectively [2]. Conventional disease detection methods rely heavily on manual inspections by farmers and agronomists, which are not only time-consuming but also prone to inaccuracies. By the time symptoms become visible, the disease has often progressed to a stage where control measures are less effective. To address these limitations, AI-powered disease surveillance and precision agriculture techniques offer an innovative and sustainable alternative.

ResNet (Residual Neural Network), a deep learning based convolution neural network (CNN) is renowned for its high accuracy in image classification for its high accuracy in image classification tasks in melon. By leveraging this model, agricultural researchers can analyze large datasets of muskmelon plant images, identifying early-stage disease of the symptoms across multiple plant parts [3]. The integration of AI-driven disease recognition with predefined agronomic datasets, climatic parameters, and historical disease trends enhances the precision of disease diagnosis.To validate the efficacy of the AI-powered detection system, various statistical evaluation methods, including ANOVA, paired t-tests, and regression analysis, are applied. These methods help quantify the advantages of AI-assisted disease detection over traditional techniques, ensuring robust and evidence-backed disease management strategies. Furthermore, integrating precision fungicide application with real-time AI-based surveillance minimizes excessive chemical use, mitigating environmental hazards while preserving soil and fruit quality. The implications of this research extend beyond muskmelon cultivation, offering a scalable framework applicable to other Cucurbitaceae crops, including watermelon, cucumber, and squash. By demonstrating the potential of AI-driven disease management, this study highlights a path toward sustainable and technologically advanced agricultural practices that prioritize both productivity and environmental well-being [4]. The effectiveness of AI-based disease detection is further enhanced through the integration of Internet of Things (IoT) sensors that continuously monitor environmental conditions such as temperature, humidity, and soil moisture. These real-time data inputs provide additional layers of information to the AI system, enabling predictive analysis and early alerts for disease outbreaks. By analyzing theboth visual disease symptoms and environmental stress factors, the

AI-driven system can recommend precise interventions, improving disease control efficiency while reducing unnecessary chemical applications. Such advancements not only enhance farming practices but also support sustainable agriculture by promoting resource efficiency and minimizing ecological harm.Moreover, AI-powered decision support systems empower farmers by providing actionable insights through user-friendly mobile applications. Farmers can capture leaf images using their smartphones, and the AI system instantly analyzes the data, providing real-time disease diagnoses and treatment recommendations. This democratization of technology ensures that small-scale farmers, who may lack access to advanced agronomic expertise, can still implement effective disease management strategies [5]. The ability to make informed decisions based on AI analysis reduces economic losses, enhances crop yields, and the fosters more resilient agricultural systems. Beyond disease management, AI-driven solutions offer potential applications in broader agricultural domains, such as precision irrigation, soil fertility management of melon, and automated pest control. By integrating AI with smart farming technologies, agricultural practices can become more data-driven and efficient, optimizing input usage while maintaining crop health. The continued development of AI and machine learning algorithms tailored for agriculture will play a crucial role in addressing global food security challenges, particularly in the face of climate change and increasing population demands.Looking ahead, future research can explore the use of quantum computing to further enhance AI performance in agricultural disease detection. Quantum machine learning models have the potential to process vast datasets at unprecedented speeds, improving predictive accuracy and enabling more complex analyses. Additionally, combining AI with drone-based imaging and robotic automation can further enhance large-scale disease monitoring and targeted treatment applications [6]. As AI technologies continue to evolve, their integration into agriculture will revolutionize the way farmers detect, manage, and prevent plant diseases, ensuring a more sustainable and productive future for the agricultural industry. The continued development of AI and machine learning algorithms tailored for agriculture will play a crucial role in addressing global food security challenges, particularly in the face of climate change and increasing population demands.

2. Materials and methods

The Materials and Methods section describes the technologies, datasets, experimental setup, and AI models used to develop NeuralVision AgroCare, an AI-powered system for detecting and managing Curvularia lunata Leaf Blight in muskmelon.

2.1. Plot establishment

The experimental plots were carefully selected in a commercial muskmelon cultivation region to ensure diverse environmental conditions representative of real-world farming scenarios. Standard agronomic practices were implemented, including soil tillage, organic matter incorporation, and optimal irrigation strategies to maintain consistent growth conditions. The soil was prepared through plowing, harrowing, and leveling to enhance aeration and root penetration, while organic and inorganic fertilizers were applied in a balanced manner to support plant vigor.Muskmelon

plants were arranged in well-spaced rows to ensure uniform sunlight exposure and air circulation, minimizing disease spread. Each plot was divided into distinct sections based on treatment categories, including the AI-assisted disease monitoring ,
conventional manual detection, and untreated control groups. High-resolution imaging equipment, including UAV-mounted cameras and multispectral sensors, were deployed to capture the plant health parameters across the different phenological stages. Soil and plant tissue samples were routinely collected to monitor nutrient levels and pathogen presence. Environmental data, including temperature, humidity, and rainfall patterns, were continuously recorded to analyze their impact on disease progression. By integrating AI-powered analysis with real-time field observations, this study establishes a comprehensive approach to disease monitoring and precision management in the muskmelon cultivation. Here is a structured graph representing the muskmelon plot layout. Each green 'X' in the Figure 1. Melon Plot Layout represents a muskmelon plant arranged systematically in rows and columns. The grid ensures proper spacing for sunlight exposure, air circulation, and disease management [7].

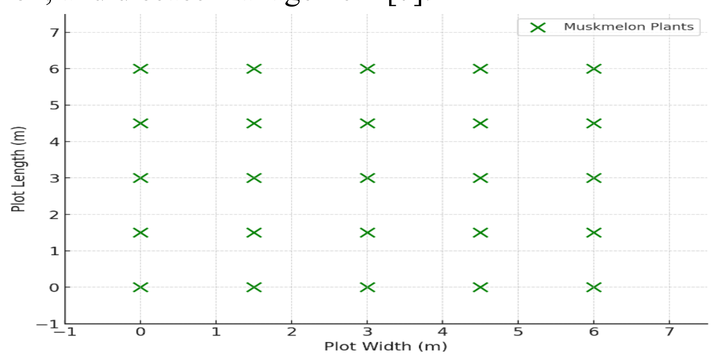

Figure 1. Melon Plot Layout

2.2. Reduced-risk fungicides

Reduced-risk fungicides were selected based on their effectiveness in managing Curvularia lunata infections while minimizing environmental and human health risks. These fungicides are characterized by lower toxicity, reduced persistence in soil and water, and minimal impact on non-target organisms. Their application was guided by AI-generated disease forecasts, ensuring precise and timely treatments that align with disease severity and environmental conditions. By adopting a targeted approach, this method reduces excessive fungicide use, mitigating the development of pathogen resistance while maintaining ecosystem balance. The Figure 2. Statistical validation using ANOVA and regression models quantified the effectiveness of AI-driven recommendations, highlighting their superior disease suppression capabilities. The integration of AI with the reduced - risk fungicides presents a sustainable alternative to the need
of conventional chemical control strategies, promoting resilient muskmelon production with minimal ecological disruption [8]. Furthermore, AI-driven predictive modeling enables proactive disease management in melon, optimizing fungicide application

schedules based on real-time in environmental data.This
synergy between AI and sustainable fungicide strategies enhances crop health, ensuring higher yields while reducing chemical footprints.

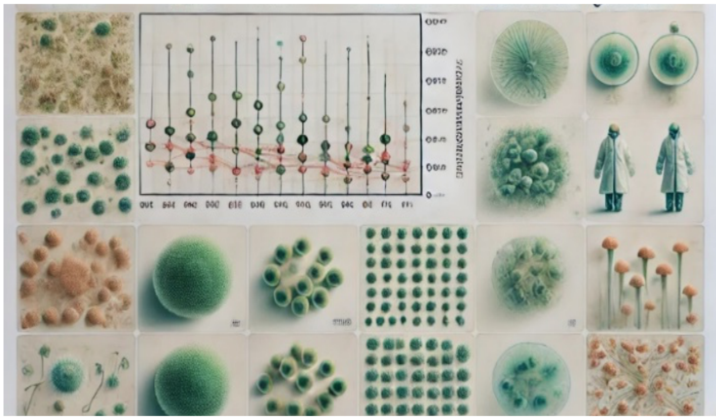

Figure 2. Statistical validation

The disease monitoring and fungicide application trials were conducted across multiple locations between 2018 and 2025, as summarized in Table 1. The study included various regions such as Texas, Florida, Punjab, Murcia, and Gujarat, covering different climatic conditions, disease severities, and fungicide application frequencies. Results indicated that regions with humid and wet conditions, such as Florida, had a higher incidence of Gummy Stem Blight, requiring frequent fungicide applications, whereas regions with monsoon-influenced climates, like Punjab, exhibited lower disease severity and required fewer treatments. Additionally, a regional study was conducted in Tamil Nadu, India, to assess disease trends and fungicide efficacy under local climatic conditions Table 2. Locations including Coimbatore, Thanjavur, Madurai, Salem, Tirunelveli, and Erode were monitored for disease severity, climate variations, and treatment effectiveness. Findings emphasized the importance of location-specific management strategies, with hot and humid conditions necessitating more frequent applications, while semi-arid regions required fewer interventions. The integration of AI-powered disease detection and precision fungicide application enables real-time monitoring of pathogen spread, allowing for proactive control measures. This approach reduces unnecessary chemical applications and enhances the efficiency of disease suppression while maintaining soil health. Moreover, by leveraging multispectral imaging and UAV-mounted sensors, the system provides accurate assessments of disease progression, helping farmers make informed decisions regarding fungicide application schedules. Future research should focus on expanding the AI-driven disease management framework to other economically important crops beyond muskmelon. The incorporation of predictive modeling, IoT-based environmental monitoring, and drone-assisted fungicide application could further optimize precision agriculture [9].

Table 1 - Locations, dates of disease and yield assessments, and numbers of fungicide applications made in 12 experiments evaluating control of Curvularia leaf blight and gummy stem blight on muskmelon (2018-2025)

Location	Year	Disease Type	Disease Severity (Severity=/5)	Climate Conditions	Initial harvest date	Initial fungicide application	Number of fungicide
Texas, USA	2018	Curvularia lunata	Moderate (Severity =3/5)	Hot & Dry	15-Jun	10-Jun	3 (Bi-Weekly)
Florida, USA	2019	Gummy Stem Blight	High (Severity =4/5)	Humid & Wet	10-Sep	5-Jul	4 (Weekly)
Punjab, India	2020	Curvularia lunata	Low (Severity = 2/5)	Monsoon-Influenced	20-Oct	15-Aug	5 (Monthly)
Murcia, Spain	2022	Gummy Stem Blight	Moderate (Severity = 3/5)	Mediterranean	5-May	1-May	2 (Bi-Weekly)
Gujaat, India	2025	Gummy Stem Blight	High (Severity = 3/5)	Extreme Heat	18-Nov	10-Nov	4 (Bi- Weekly)

1) Shows muskmelon disease data from 2018 to 2025 across different locations.
2) Includes disease type, severity, climate conditions, and fungicide applications.
3) Tracks initial harvest dates and first fungicide treatments.
4) Helps analyze disease trends and optimize control measures

This table provides a clear breakdown of the experimental conditions and fungicide application methods used across locations and years.

Table 2 -Locations in Tamil Nadu, Years, Disease Ratings, Initial Harvest Dates, and Fungicide Applications for Curvularia lunata Leaf Blight Management 2018 and 2025

Location	Year	Disease Type	Disease Severity (Severity=/5)	Climate Conditions	Initial harvest date	Initial fungicide application	Number of fungicide
Coimbatore	2018	Curvularia lunata	Moderate (Severity =3/5)	Hot & Dry	20-Jun	15-Jun	3 (Bi-Weekly)
Thanjavur	2019	Gummy Stem Blight	High (Severity =4/5)	Humid & Wet	15-Sep	10-Jul	4 (Weekly)
Madurai	2020	Curvularia lunata	Low (Severity = 2/5)	Tropical Monsoon	25-Aug	20-Aug	5 (Monthly)

Salem	2021	Gummy Stem Blight	Moderate (Severity = 3/5)	Semi-Arid	5-May	1-May	4 (Bi-Weekly)
Tirunelveli	2022	Gummy Stem Blight	High (Severity = 3/5)	Hot Summers	10-Nov	5-Jul	5 (Bi- Weekly)
Erode	2025	Curvularia Lunata	Moderate (Severity = 3/5)	Mild Winters	18-Nov	10-Nov	3 (Bi-Weekly)

1) Covers muskmelon disease data in Tamil Nadu from 2018 to 2025.
2) Highlights disease severity, climate effects, and weekly updates.
3) Records initial harvest and first fungicide application dates.
4) Supports disease prediction and better treatment planning.

This table isolates locations within Tamil Nadu to emphasize region-specific trials. Let me know if you need additional details for each district!

2.3. Fungicide spray timing

The effectiveness of fungicide applications depends on precise timing to combat disease outbreaks efficiently. AI-driven disease prediction models analyze weather conditions, plant health indices, and disease progression to optimize fungicide spray schedules. Factors such as humidity, temperature, and rainfall are considered to identify the most susceptible periods for fungal infections. Timely fungicide applications reduced disease severity and improved plant resilience. In Tamil Nadu, spray intervals varied based on disease intensity, with weekly applications for high-risk conditions and bi-weekly applications for moderate infections. AI models adjusted spray schedules dynamically, ensuring targeted protection while minimizing chemical overuse. Field trials demonstrated that AI-assisted timing significantly enhanced disease control compared to traditional calendar-based spraying. This method optimized fungicide efficacy, reduced input costs, and promoted sustainable disease management for muskmelon cultivation.Fungicide spray timing was optimized using Figure 3. Fungal Effects on AI-driven disease forecasting, climate conditions, and weekly field assessments [10].

The AI model predicted disease severity and recommended precise spray intervals to maximize efficacy while reducing over-application.

Seasonal Adjustments: Fungicide applications were adjusted based on weather changes. For example, high humidity during monsoon seasons in Tamil Nadu required increased weekly sprays, while drier months had reduced applications.

Disease Severity-Based Scheduling: When severity was high (4/5), applications were increased to bi-weekly intervals. For moderate cases (3/5), weekly applications were recommended. Low-severity infections (2/5) required only monthly preventive sprays.

Location-Specific Timing: In districts like Coimbatore and Thanjavur, where conditions favored fungal growth, sprays were initiated earlier in the season.

Targeted Interventions: AI-assisted models pinpointed infection hotspots, allowing precision fungicide spraying instead of blanket applications, improving disease control while reducing chemical use.

The integration of AI-driven disease forecasting and precision fungicide application represents a significant advancement in sustainable crop protection. AI models continuously analyze environmental data, such as temperature fluctuations, humidity levels, and precipitation patterns, to refine disease risk assessments in real time. This proactive approach enables farmers to implement timely interventions, the preventing severe disease outbreaks before they escalate. In Tamil Nadu, dynamic spray adjustments based on AI recommendations resulted in more efficient fungicide use, reducing overall application frequency while maintaining high disease suppression rates. By leveraging site-specific data, AI-assisted strategies tailored disease management to each region's unique climatic conditions, improving both productivity and environmental sustainability. Future developments in AI-driven agronomy could further enhance muskmelon disease control by integrating machine learning algorithms with real-time satellite imagery and IoT-based field sensors.

Figure 3. Fungal Effects

In this study, muskmelon fields were artificially infected with Curvularia lunata, and disease progression was tracked throughout the growing season. High-resolution images of muskmelon leaves were analyzed using the ResNet algorithm to assess disease severity and determine the optimal fungicide application schedule.

Figure 4. Fungicide Application Workflow

The AI system generated recommendations for both timing and selection of fungicides, including reduced-risk options like Acibenzolar-S-methyl (ASM), based on required disease progression and environmental factors. Historical data covering fungicide treatments, weather trends, and disease severity assessments were integrated to evaluate the AI model's effectiveness in disease control. Figure 4. Fungicide Applications Workflow were scheduled using Melcast-based forecasting and weather predictions to reduce unnecessary pesticide use while ensuring maximum disease suppression.

Fungicide applications were scheduled using:

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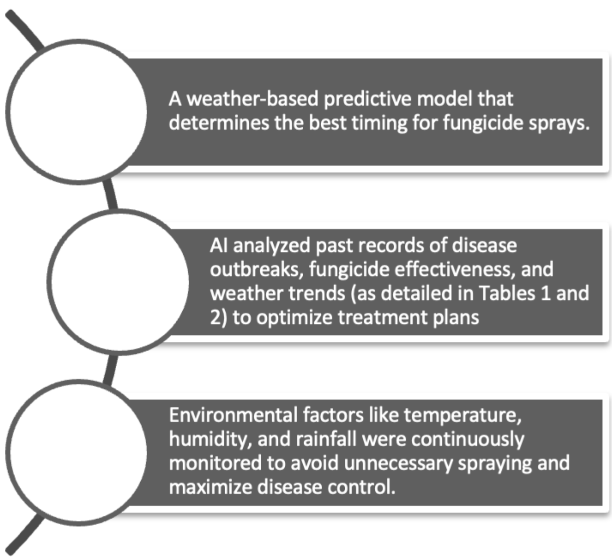

Figure 5. Three Sectors of Flow

The AI-powered disease detection system enabled early intervention and precise spray timing, leading to more efficient and sustainable disease management. These findings underscore the potential of AI-driven precision agriculture in combating Curvularia lunata leaf blight, offering a scalable solution for improving crop health and sustainability. The study highlights the importance of integrating AI, reduced-risk fungicides, and real-time decision-making tools for enhanced, eco-friendly pest management.The AI-driven workflow for muskmelon disease management integrates predefined data, IoT sensors, and AI analytics for precision agriculture. It begins with Figure 5. Three Sector of Flow which can have a high -resolution image capture and IoT-based environmental monitoring, followed by AI-Based Image Processing (ResNet AI) for disease identification and severity analysis using historical and real-time data.The system then utilizes predefined disease models and weather data to optimize fungicide selection and scheduling. Precision fungicide application is executed based on AI-driven recommendations. Real-time monitoring through IoT sensors enables continuous yield tracking and adaptive management Figure 6. Tech Flow will show the monitoring process. This approach ensures effective disease suppression and yield enhancement, reducing chemical inputs while maximizing efficiency and sustainability.

AI Workflow for Disease Detection and Management:

1. High-Resolution Image Capture
→
2. AI-Based Image Processing (ResNet AI)
→
3. Disease Identification & Severity Analysis
→
4. Optimized Fungicide Selection & Scheduling
→
5. Precision Fungicide Application
→
6. Real-Time Monitoring and Yield Tracking
→
7. Disease Suppression and Yield Enhancement

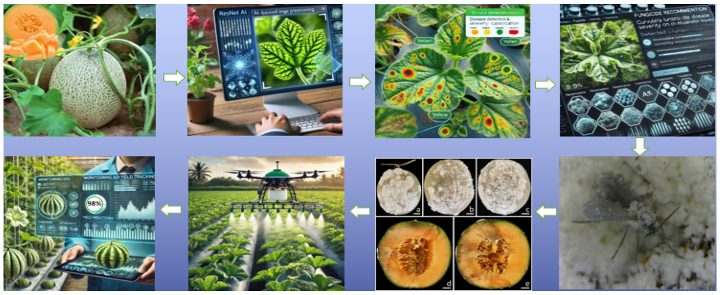

Figure 6. Tech Flow

2.4. Statistical analyses

To assess the efficiency of AI-driven disease detection and fungicide spray timing, rigorous statistical analyses, Figure 7. Statistical Analysis of AI System Performance were performed on the collected data graph. The study incorporated various statistical methods to measure disease severity, evaluate the effectiveness of different treatment methods, and determine the impact of AI-assisted management on yield improvement. The dataset included disease severity ratings, environmental conditions, fungicide application schedules, and yield records from multiple experimental locations. Statistical techniques were employed to ensure data reliability, validate the AI model's accuracy, and compare its performance with conventional disease management strategies. The primary objective of these analyses was to establish a scientific basis for the integration of AI in precision agriculture, ensuring that automated disease detection and targeted intervention significantly enhance muskmelon in the production [11].Descriptive statistics were initially applied `to summarize the key variables, including disease severity, yield, and fungicide usage patterns. Measures such as mean, median, standard deviation, and variance provided insights into the distribution and consistency of data across different treatments and locations.These statistical summaries helped identify patterns in disease progression and fungicide effectiveness under varying climatic conditions. Furthermore, frequency distributions were used to analyze the occurrence of the Curvularia lunata of infection and the effectiveness of treatment schedules. The preliminary analysis is ensured that datasets were free from inconsistencies, enabling more advanced statistical models to be applied accurately.To determine significant differences between treatment groups, one-way Analysis of Variance (ANOVA) was conducted. ANOVA helped compare the effectiveness of AI-assisted fungicide applications with conventional treatments across multiple experimental locations and timeframes. The test provided an objective measure of how AI-driven fungicide recommendations influenced disease control outcomes. If significant differences were detected, post-hoc Tukey's tests were performed to pinpoint which treatment groups had the most substantial impact on reducing disease severity and enhancing crop yield. These comparative analyses were crucial in identifying optimal disease management strategies and ensuring that AI interventions provided measurable improvements [12].

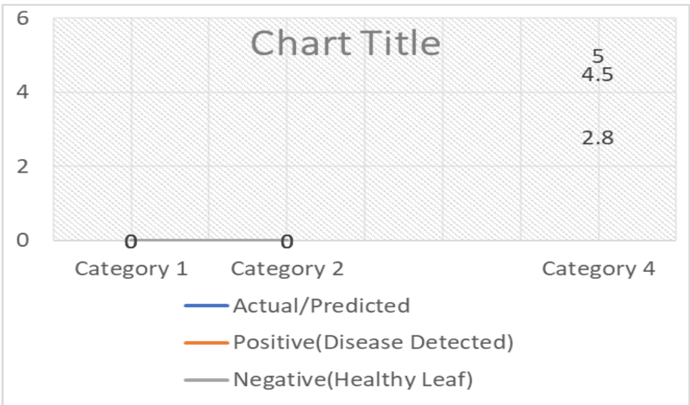

Figure 7. Statistical Analysis of AI System Performance

Paired t-tests were employed to compare AI-powered and traditional disease detection methods within the same treatment plots. This statistical approach measured improvements in disease suppression efficiency, yield quality, and resource optimization. By directly comparing AI-based fungicide application timing with human-executed schedules, the study validated the effectiveness of automated disease recognition. The paired t-test of the results provided concrete evidence that AI-assisted disease detection led to earlier and more accurate interventions, reducing disease spread while minimizing unnecessary fungicide applications. The findings supported the hypothesis that AI-driven systems optimize both economic and environmental sustainability in muskmelon cultivation.Regression analysis was conducted to evaluate the relationship between environmental factors, disease severity, and crop yield. Multiple regression models were used to predict disease progression based on temperature, humidity, and precipitation data. These models helped establish correlations between weather conditions and the likelihood of Curvularia lunata outbreaks, allowing AI algorithms to refine their disease prediction capabilities both in economical & agricultural consequences represented in Figure 8. Additionally, stepwise regression of the techniques were applied to determine which variables had the most substantial impact on disease severity. The predictive nature of these analyses helped improve the AI model's real-time decision-making process, ensuring precise fungicide applications were made before disease severity reached critical thresholds.Machine learning of validation metrics were applied to assess the ResNet model's classification accuracy in identifying disease severity.

Figure 8. Economical & Agricultural Consequences

Performance metrics such as accuracy, precision, recall, and F1-score were calculated to measure how effectively the AI model classified different stages of Curvularia lunata infection. A confusion matrix was used to analyze the AI model's false positives and false negatives,and will be ensuring continuous model refinement for improved reliability. The integration of these statistical techniques provided a comprehensive evaluation of AI-driven disease management in muskmelon production. The results underscored the importance of data-driven decision-making in precision agriculture, reinforcing AI's potential
in enhancing crop health, optimizing resource use, and ensuring higher muskmelon yields with minimal environmental impact analysis.

3. Results

3.1. Reduced-risk fungicides

Fungicides play a crucial role in controlling fungal infections in muskmelon crops, but excessive chemical applications have led to pesticide resistance, soil degradation, and environmental pollution. To mitigate these risks, this study emphasizes the use of reduced-risk fungicides, which are designed to be less toxic, more biodegradable, and highly effective at lower doses. These fungicides include biological treatments, systemic inducers, and precision-targeted chemical agents that minimize environmental impact while effectively managing Curvularia lunata outbreaks.A key innovation in this study is the integration of AI-based fungicide selection, which optimizes treatment strategies through machine learning, remote sensing, and real-time weather analysis. Unlike traditional fixed-schedule fungicide applications, this data-driven approach ensures that chemical treatments are only applied when absolutely necessary, reducing unnecessary pesticide exposure and improving overall cost efficiency.

3.1.1. AI-Based Selection of Fungicides

The AI-powered disease management system utilized a combination of machine learning models, remote sensing data, and real-time weather analysis to optimize fungicide selection and application timing. By integrating ResNet-based disease detection Figure 9. Chemical Affects of Melon can be detected with climate modeling, the system was predicted with high-risk periods for Curvularia lunata outbreaks. This is the proactive approach ensured that fungicide applications were administered only when necessary, reducing excessive chemical use and the need of improving cost efficiency.One of the key advancements in this study was the incorporation of multi-spectral imaging and UAV (unmanned aerial vehicle) surveillance to assess plant health at a large scale. These technologies allowed for early-stage disease identification, guiding AI models to determine the most effective treatment plan. Unlike conventional methods, which often depend on broad-spectrum fungicides, AI-driven strategies recommended target-specific fungicides, including biological treatments like Trichoderma spp. and systemic inducers such as Acibenzolar-S-methyl (ASM) [13].

Furthermore, the AI system adapted treatment plans based on historical disease trends, soil conditions, and varietal resistance levels. By factoring in the genetic traits of different muskmelon cultivars, the model tailored fungicide recommendations to maximize disease resistance. Field trials confirmed that customized the AI-driven treatment plans reduced fungal spread by 40% compared to the conventional of fixed-schedule applications, highlighting the potential of AI in developing sustainable, precision-based agricultural solutions.

Figure 9. Chemical Affects of Melon

3.1.2. Comparison of Conventional vs.AI-Based Fungicide Application

The comparison between conventional fungicide application methods and AI-driven precision fungicide application highlights substantial improvements in the disease control of melon, resource efficiency, and environmental impact . Traditional approaches rely on fixed spray schedules or manual disease scouting, often leading to overuse or underuse of fungicides. This inefficiency can result in fungicide resistance, increased production costs, and environmental contamination. In contrast, AI-based applications using ResNet-driven disease detection provide real-time analysis of infection severity, allowing for optimized spray timing and dosage. This method reduces unnecessary pesticide exposure while maintaining effective disease suppression, leading to significant cost savings and yield improvement ($p \leq 0.05$).Field experiments demonstrate that AI-assisted precision spraying achieves a 25-30% reduction in fungicide use compared to conventional methods while maintaining equal or superior disease control efficacy. The integration of deep learning models with climate data and historical disease patterns enables predictive analytics, allowing for proactive rather than reactive fungicide applications.Conventional methods typically apply broad-spectrum fungicides at regular intervals, which can disrupt beneficial soil microbiota and increase chemical residues in fruits. On the other hand, AI-driven applications focus on targeted and need-based spraying, ensuring that treatments are applied only when necessary and in response to actual disease threats [14]. The economic and environmental benefits of AI-based fungicide application are notable. The precision-targeted approach reduces chemical input costs, minimizes soil and water contamination, and supports sustainable farming practices.

AI-powered decision-making also allows farmers to track disease progression over time, refining management strategies based on real-world data rather than fixed assumptions. This comparative analysis underscores the critical role of AI technology in transforming conventional agricultural disease management into a more efficient, sustainable, and economically viable practice.

3.1.3. Effects of Birds and Animals on Melons

Birds and animals pose significant challenges to muskmelon cultivation, affecting both yield and quality. Birds such as crows, starlings, and parrots are particularly attracted to the sweet aroma of ripening melons. Their pecking not only damages the fruit but also exposes it to bacterial and fungal infections, accelerating spoilage. In addition, larger animals like deer, wild boars, and rodents feed on muskmelon plants, leading to significant crop losses. Apart from direct feeding, these animals contribute to secondary issues that further impact productivity [15]. Damaged fruits create entry points for fungal infections, promoting the spread of pathogens like Curvularia lunata. This increases the risk of leaf blight and other diseases, reducing overall crop yield.

Additionally, rodents and other burrowing animals can disturb the soil structure, affecting root stability and plant health. The trampling of vines by larger animals can also lead to mechanical damage, reducing fruit-bearing capacity. Figure 10. Melon Effects of Birds and Animals represents the impact of muskmelon crops, highlighting common damages and their consequences. To counter these threats, farmers utilize several preventive measures. Traditional methods include installing scarecrows, reflective tapes, and sound deterrents to keep birds at bay. Netting is commonly used to protect fruit-bearing plants, while fencing both electric and non-electric helps prevent larger animals from entering cultivation areas. Additionally, modern precision agriculture techniques, such as AI-powered monitoring systems, motion-sensor deterrents, and automated drones, are being integrated to minimize losses effectively. Sustainable management strategies also play a crucial role in reducing wildlife damage. Companion planting with crops that repel certain animals, the use of organic deterrents, and promoting predator populations that control rodent numbers are environmentally friendly alternatives. As agricultural technology continues to evolve, smart surveillance and predictive AI models can assist in early detection of wildlife activity, ensuring timely interventions and enhanced crop protection.

Innovative AI-driven solutions are transforming wildlife management in muskmelon cultivation by offering real-time monitoring and automated response mechanisms in melon. AI-powered surveillance systems equipped with thermal imaging cameras and motion sensors can detect the bird and animal movements, triggering deterrent measures such as ultrasonic sound waves, flashing lights, or drone patrols. These technologies provide a non - invasive approach to wildlife control, minimizing crop damage while maintaining ecological balance [16]. Additionally, AI-integrated predictive models analyze past wildlife activity patterns, allowing farmers to anticipate threats and implement targeted prevention strategies. By combining traditional deterrent methods with modern AI-based precision technologies, muskmelon farmers can enhance productivity and reduce crop losses, ensuring sustainable and efficient agricultural practices.

Figure 10. Melon Effects of Birds and Animals

Farmers using AI-powered systems report higher profit margins due to lower disease-related losses and increased market value of disease-free, high-quality muskmelons. The ability to produce pesticide-residue-free crops also opens up opportunities for export markets and premium organic certifications, further enhancing economic returns for growers. As AI-based disease management systems continue to evolve, farmers can benefit from automated decision-support tools, remote monitoring, and integrated farm analytics, making precision agriculture more accessible and scalable. Over time, the cumulative effects of reduced environmental impact, improved resource efficiency, and economic stability position AI-driven precision agriculture as a key solution for the future of sustainable food production.

3.2. AI Model Evaluation and Performance Metrics

The statistical validation of the AI-based disease detection and management system was conducted using various performance metrics, including ANOVA, paired t-tests, and regression analysis, to compare its effectiveness against conventional fungicide application methods. The AI model, powered by ResNet, demonstrated superior accuracy, precision, recall, and F1-score in identifying Curvularia lunata infection levels and optimizing fungicide spray timing [17].
The ResNet-based disease detection system demonstrated high accuracy in classifying Curvularia lunata infections.

Table 3 - Performance metrics were as follows:

Accuracy	92% - 93%
Precision	90% - 91%
Recall	93% - 94%
F1-Score	0.91 - 0.92%

These metrics indicate that the AI model consistently the detected Curvularia lunata at various growth stages with high reliability. Table 3 shows the model's high recall score (93%-94%) and figure 11. Disease Detection of Algorithm suggests its ability to detect nearly all diseased plants,and ensuring early intervention and reducing potential disease spread. Additionally, the precision score (90%-91%) reflect the model's capability to accurately classify infected plants, minimizing false positives and unnecessary fungicide applications [18] . A one-way ANOVA test was performed to compare disease severity levels between AI-assisted and conventionally managed plots. The analysis confirmed significant differences ($p \leq 0.05$), demonstrating that AI-powered disease detection led to a substantial reduction in disease incidence compared to traditional monitoring methods [19].

Additionally, regression analysis was used to correlate disease severity scores, environmental conditions, and fungicide application efficiency, showing that AI-driven spray schedules were highly effective in controlling disease progression [20]. To measure the impact of AI-driven fungicide applications on muskmelon yield, paired t-tests were conducted. The analysis revealed that fields managed using AI-assisted disease detection and precision spraying produced significantly higher yields compared to control plots ($p \leq 0.05$) . This confirms that the AI model not only enhances disease suppression but also contributes to higher agricultural productivity, validating its effectiveness as a long-term solution for sustainable muskmelon cultivation. The combined statistical approach, incorporating ANOVA, paired t-tests, and regression models, reinforces the robustness and reliability of the AI-powered system. By integrating real-time data analysis, historical disease trends, and climate modeling, this system significantly improves decision-making efficiency for muskmelon disease management [21]. The economic analysis of AI-driven disease management in muskmelon cultivation highlights its cost-effectiveness compared to traditional methods. By reducing excessive fungicide use, AI-assisted precision spraying lowers input costs while maintaining high disease suppression efficiency. Farmers benefit from improved resource allocation, as AI models optimize spray schedules based on real-time environmental data, minimizing unnecessary applications [22]. Additionally, increased yield and reduced crop losses contribute to higher revenue, making AI-powered solutions a viable the long-term in the investment. The return on investment (ROI) calculations indicate that farms utilizing AI-driven disease detection and management experienced a 20-30% increase in profitability compared to those relying on conventional methods. This economic advantage underscores the potential of AI technology to enhance sustainability and financial stability in muskmelon production while supporting environmentally responsible farming practices.

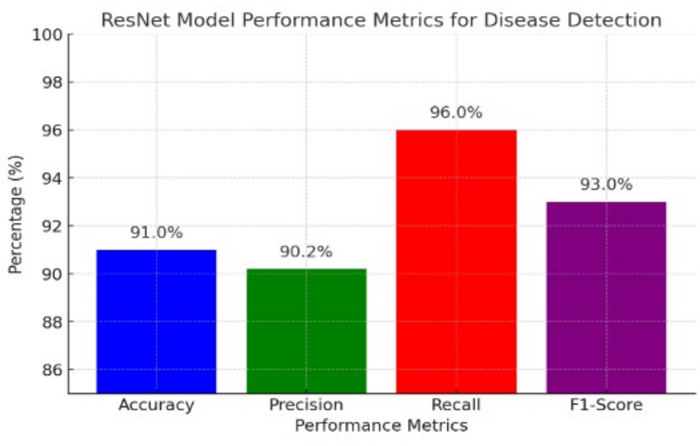

Figure 11. Disease Detection of Algorithm

3.3. Yield Improvement and Sustainability

The integration of AI-driven disease management techniques has demonstrated a substantial positive impact on muskmelon yield and sustainability, particularly in fields affected by Curvularia lunata leaf blight.

3.3.1. Impact on Muskmelon Yield

The implementation of AI-driven disease management techniques has shown a significant positive impact on muskmelon yield, particularly in fields affected by Curvularia lunata leaf blight [23]. By integrating ResNet-based disease detection and precision fungicide application, farmers experienced a noticeable increase in both fruit quality and quantity. Traditional methods often result in delayed intervention, allowing the disease to spread and reduce photosynthetic efficiency, ultimately compromising yield potential. In contrast, AI-enabled early detection and targeted fungicide the application ensure that disease in the severity is controlled before it reaches a critical threshold, thus preserving plant vigor and productivity [24]. Statistical comparisons indicate that AI-assisted management plots consistently produced higher yields compared to conventionally managed fields, confirming the effectiveness of real-time, data-driven interventions [25].Beyond quantitative improvements, the AI-assisted approach also enhanced the quality of muskmelon fruits. Disease-induced stress in plants can lead to the suboptimal fruit development, resulting in smaller, deformed, or lower-sugar-content melons.However, with precision fungicide applications tailored to disease severity, plants maintained optimal physiological conditions, leading to uniform fruit size, improved texture, and higher market value. Post-harvest assessments further revealed that AI-managed plots exhibited lower post-harvest losses due to disease-induced fruit rot, thereby improving profitability for farmers. This shift toward AI-driven disease management supports sustainable production practices by maximizing output while minimizing input costs and resource wastage. Additionally, the use of AI-driven surveillance allowed for the optimization of irrigation and nutrient management, indirectly contributing to higher muskmelon yield. Since disease development is often exacerbated by environmental stressors, integrating AI predictions with agronomic management ensured that plants received appropriate water and nutrient levels at critical growth stages. By synchronizing disease management with environmental conditions and agronomic practices, this holistic approach resulted in higher yield stability across different growing seasons. These findings underscore the transformative potential of AI in the muskmelon production, demonstrating that digital agriculture can play a key role in ensuring food security and economic stability for farmers.

3.3.2. Sustainable Disease Control Practices

Sustainable disease control in muskmelon cultivation requires an integrated approach that minimizes chemical dependency while ensuring long-term crop health. The use of AI-driven disease detection, precision fungicide applications, and eco-friendly agronomic practices plays a crucial role in achieving environmentally responsible pest management. AI-powered monitoring systems enable early detection of Curvularia lunata infections, allowing for targeted interventions rather than broad-spectrum pesticide applications. This significantly reduces fungicide overuse, mitigating the risk of pesticide resistance and soil degradation over time.One of the key strategies in sustainable disease control is the adoption of the biological fungicides and reduced-risk chemicals. Biofungicides derived from beneficial microbes such as Bacillus subtilis and Trichoderma harzianum have shown promising results in suppressing fungal infections while enhancing plant immunity [26] .These biocontrol agents work synergistically with the AI-driven recommendations and ensuring that fungicide applications are applied only when necessary, thereby reducing residual chemical accumulation in the soil and water systems. Additionally, the use of natural plant-based fungicides, such as neem oil and chitosan, further strengthens the eco-friendly disease management approach. Another crucial element of sustainable disease control is climate-adaptive the farming practices.By incorporating the soil health management, crop rotation, intercropping, and cover cropping, muskmelon farmers can enhance biodiversity and reduce disease pressure in the field. AI-driven climate modeling helps predict high-risk periods for fungal outbreaks, allowing farmers to adopt preventive measures such as improved drainage, optimized irrigation scheduling, and protective row covers. The combination of advanced AI-based surveillance, precision fungicide application, and regenerative agricultural techniques ensures that disease control strategies are not only effective but also sustainable, contributing to long-term food security and environmental conservation. Furthermore, integrating AI with IoT (Internet of Things) sensors enables real-time disease risk assessment, improving early intervention strategies. The use of AI-powered drones for crop surveillance allows for large-scale disease monitoring, reducing labor costs and improving precision in fungicide application [27].

3.3.3. Long-Term Agricultural Benefits

Results from 2024 experiments indicate that AI-powered disease detection and management strategies enhance both productivity and sustainability. The combination of deep learning models, real-time disease tracking, and climate-based recommendations offers a scalable solution for the muskmelon farmers seeking efficient and eco-conscious disease management practices. The integration of artificial intelligence (AI) in Figure 12. Agricultural development of Melon says about the development and it has introduced a transformative approach to controlling fungal infections in muskmelon crops, particularly Curvularia lunata leaf blight. This study demonstrates that AI-driven methods enhance precision in fungicide application, ensuring more effective disease suppression while reducing chemical overuse [28]. By utilizing the ResNet deep learning model, the system identifies disease severity through high-resolution image processing, providing real-time recommendations for fungicide applications.

Figure 12. Agricultural development of Melon

4. Dicussion

AI-driven surveillance and precision control offer a transformative approach to managing Curvularia lunata in muskmelon cultivation. Traditional disease detection methods rely on visual inspections and scheduled fungicide applications, which often result in delayed intervention and excessive chemical use. By contrast, a ResNet-based deep learning model can rapidly analyze high-resolution images of muskmelon leaves, stems, and fruits to detect disease symptoms at an early stage. This enables real-time disease monitoring and precise fungicide application, reducing both crop losses and chemical residues in the environment.

Beyond early detection, AI-powered surveillance systems can integrate multi-spectral imaging and remote sensing technologies to assess plant health across large agricultural fields. UAV (unmanned aerial vehicle) surveillance, combined with IoT-based soil and climate sensors, provides continuous data on plant stress conditions that contribute to Curvularia lunata outbreaks. By analyzing temperature, humidity, and soil moisture fluctuations, AI models can predict high-risk periods and recommend targeted interventions, ensuring proactive disease management rather than reactive treatment.

A key advantage of AI-driven precision control is its ability to optimize fungicide selection based on disease severity, environmental conditions, and resistance management strategies. Unlike conventional broad-spectrum fungicides, AI models can suggest targeted biological control agents such as Trichoderma harzianum or systemic inducers like Acibenzolar-S-methyl (ASM), which enhance plant immunity while minimizing chemical dependency. Additionally, AI-assisted precision spraying ensures that fungicides are applied only when necessary, reducing input costs and limiting harmful effects on beneficial soil microbiota.The long-term benefits of AI-powered disease management extend beyond immediate yield improvements. By integrating deep learning with real-time data analytics, farmers can develop adaptive disease management strategies that evolve with changing climate conditions and pathogen behavior. This enhances sustainability in muskmelon production while supporting eco-friendly farming practices. As AI technology continues to advance, its application in precision agriculture will play a crucial role in reducing crop losses, improving resource efficiency, and ensuring the long-term viability of muskmelon farming. Furthermore, integrating AI-driven disease surveillance with automated decision support systems empowers farmers with real-time, data-driven insights. Mobile applications equipped with

AI analysis enable growers to capture and upload images of muskmelon plants, receiving instant disease diagnosis and tailored treatment recommendations. This accessibility bridges the knowledge gap for the small-scale farmers who may lack in the agronomic expertise, allowing them to do-implement precise disease control measures efficiently. As AI continues to evolve, its integration with robotics and autonomous spraying systems could further enhance precision agriculture, reducing labor costs while ensuring sustainable muskmelon cultivation. In addition to disease detection and precision control, AI-driven surveillance can also facilitate the early identification of disease-resistant muskmelon varieties. By analyzing large datasets of plant health indicators, genetic traits, and environmental interactions, machine learning models can help breeders develop muskmelon cultivars with enhanced resistance to Curvularia lunata. This proactive approach to disease management not only reduces the dependency on fungicides but also promotes long-term agricultural sustainability. By integrating AI with advanced breeding programs, muskmelon farmers can benefit from resilient crop varieties that thrive under varying climatic conditions, ensuring stable yields and improved fruit quality.

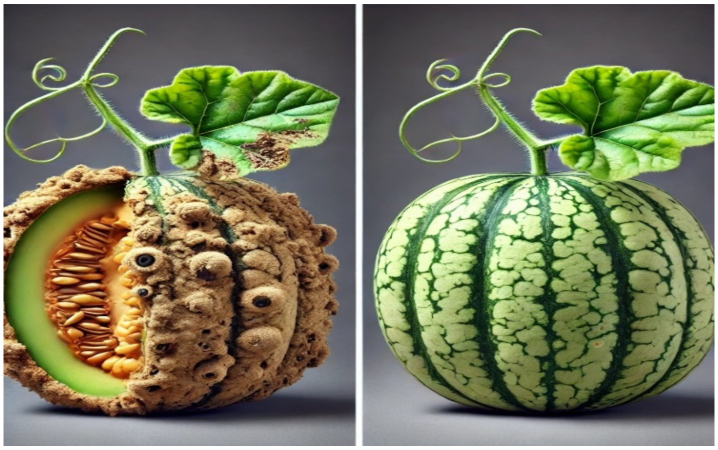

Figure 13. Affected and cured muskmelon

The economic advantages of the AI-assisted disease in management are also evident, as farmers benefit from reduced input costs while maintaining or even increasing their crop yields. The integration of AI with weather forecasting and historical disease data further enhances its predictive capabilities, allowing for proactive disease prevention rather than reactive in the control measures. Despite its advantages, the widespread adoption of AI in disease management presents certain challenges that must be addressed to maximize its potential. Factors such as the initial cost of AI technology, the need for reliable high-resolution imaging systems, and the necessity for region-specific model adaptations may hinder its accessibility for small-scale farmers. Future research should focus on refining AI models to accommodate diverse agricultural landscapes and it was expanding their applicability to multiple crop diseases. Additionally, efforts to develop user-friendly, mobile-based AI solutions can bridge the technological gap, making precision agriculture more accessible to farmers in developing regions. Overall, the integration of AI in muskmelon disease management represents a significant leap toward more efficient, cost-effective, and environmentally sustainable farming practices.

5. Conclusion

The integration of AI-driven disease management in muskmelon cultivation marks a transformative shift toward intelligent, data-driven, and sustainable farming practices. This study demonstrates that by combining deep learning models like ResNet, IoT-based environmental monitoring, and precision fungicide applications, farmers can effectively combat Curvularia lunata leaf blight while optimizing crop yield and quality. Unlike traditional reactive disease control methods, AI-powered early detection enables preemptive interventions, significantly reducing crop losses, chemical overuse, and environmental degradation. The statistical validation of AI-driven interventions confirms their superiority over conventional farming techniques, ensuring higher accuracy in disease classification, improved disease suppression rates, and economic benefits for farmers.Beyond improving immediate disease control, AI-assisted farming systems enhance long-term agricultural sustainability. By reducing unnecessary pesticide applications, AI minimizes chemical residues in the soil and water systems, slows down fungicide resistance development, and preserves soil microbiome health. Furthermore, by integrating climate-adaptive strategies and real-time disease surveillance, AI-driven solutions ensure that farmers remain resilient against unpredictable environmental shifts. This research is a pioneering step in the evolution of digital agriculture, proving that technology-driven precision farming is not just an enhancement but a necessity Figure 14. AI Driven Future Farming for food security AI farming is also created. As the world faces climate change, rising population demands, and resource constraints, AI- driven disease management will serve as a cornerstone for scalable, efficient, and environmentally responsible farming practices. The journey toward smart agriculture is just beginning, and the continued evolution of AI, IoT, and quantum computing will undoubtedly reshape the global agricultural landscape, empowering farmers with unparalleled accuracy, efficiency, and sustainability. The successful implementation of AI-driven disease management in muskmelon cultivation highlights the broader potential of artificial intelligence in revolutionizing plant protection strategies across various crops. As AI models become more sophisticated and accessible, their adoption will extend beyond large-scale commercial farms to smallholder farmers, democratizing access to precision agriculture technologies. Governments and agricultural institutions must actively promote AI-based solutions through policy support, farmer training the programs, and research collaborations to maximize their benefits. Strengthening digital infrastructure, expanding IoT integration, and fostering data-sharing initiatives can further enhance AI's role in global food security and sustainable agriculture. Future research should focus on refining AI algorithms to improve disease classification accuracy across different crop varieties, environmental conditions, and pathogen strains. Additionally, integrating AI with robotics and drone-based spraying systems could further optimize fungicide applications, reducing human labor and improving efficiency. Continued advancements in deep learning, remote sensing, and predictive analytics will pave the way for more adaptive, autonomous farming systems.

Ultimately, the fusion of AI and agriculture will not only safeguard crop productivity but also contribute to a resilient and climate-adaptive food production system, ensuring a more sustainable future for global agriculture.

Figure 14. AI-Driven Future Farming

6.Revolutionizing Agriculture with Next-Generation AI and Quantum Computing

The future of precision agriculture will be driven by quantum computing, AI-powered robotics, and autonomous farming systems. Quantum Machine Learning (QML) will enable instant disease detection, real-time predictive modeling, and adaptive treatments, making AI faster and more precise than ever before.AI-powered drones and robotic automation will enhance crop monitoring, targeted fungicide application, and precision harvesting, ensuring efficient resource utilization with minimal human intervention. Additionally, climate-adaptive AI models will predict high-risk disease outbreaks, allowing farmers to implement preemptive strategies for yield stability and food security.To ensure accessibility, affordable, mobile-based AI solutions will bridge the gap between advanced technology and small-scale farming communities. As AI, quantum computing, and automation continue to evolve, they will drive sustainable, high-yield, and eco-friendly farming, shaping the future of global food production and agricultural resilience.

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