



Review Article

# Global trend of agricultural precision for plant pathology: Bibliometric study in Scopus database

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## ARTICLE INFORMATION



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## ABSTRACT

This bibliometric study investigates the global trends in agricultural precision within plant pathology, utilizing data from the Scopus database. This research identifies key research hubs, influential authors, and emerging themes in the domain by analyzing publication patterns, citation metrics, and keyword co-occurrence. The study highlights the increasing integration of advanced technologies such as remote sensing, machine learning, and big data analytics in plant pathology research. The findings underscore the growing emphasis on precision agriculture to enhance disease detection, management, and crop productivity. This comprehensive analysis provides valuable insights for researchers, policymakers, and practitioners aiming to leverage technological advancements for sustainable agricultural practices.

**Keywords:** Citation metrics; Disease detection; Machine learning; Remote sensing; Sustainable agriculture

## 1. Introduction

Precision agriculture has emerged as a critical approach to enhancing crop productivity and sustainability in rapidly evolving (Bala & Bansal, 2024; Banerjee et al., 2024; Chaudhari et al., 2023; Cholachgudda et al., 2022; Chouhan et al., 2020a; Jeger et al., 2021; Jindal et al., 2023; Nalla et al., 2020; Puranik et al., 2024; Salman et al., 2023; Sannakki et al., 2013; Sharma et al., 2021; Su et al., 2023). This paradigm shift is characterized by applying advanced technologies such as remote sensing, machine learning, and big data analytics to monitor, manage, and optimize agricultural practices (Almadhor et al., 2021; Arman et al., 2023; Nancy et al., 2022; Pallathadka et al., 2022; Sarkar et al., 2016; Veredas et al., 2015; Yamati et al., 2023). Precision agriculture aims to increase efficiency by providing targeted interventions based on real-time data, reducing resource wastage and environmental impact (Puranik et al., 2024; Sannakki et al., 2013; Sharma et al., 2024; I. Sharma et al., 2021).

Plant pathology, a key component of agricultural science, has significantly benefited from the integration of precision agriculture (Sharma et al., 2024; Sharma et al., 2021). Precisely detecting and managing plant diseases is crucial for ensuring food security and minimizing economic

losses (Jeger et al., 2021; K R et al., 2023; Ristaino et al., 2021). Traditional disease detection and control methods often rely on visual inspections and broad-spectrum treatments, which can be time-consuming and less effective. Therefore, precision agriculture introduces a more nuanced approach, utilizing technology to detect diseases early and implement targeted treatments, improving disease management and crop health (Khuwaja et al., 2023; Mahlein et al., 2024; Ristaino et al., 2021; Sharma et al., 2024; Sharma et al., 2021; Verma et al., 2020).

Bibliometric analysis is a powerful tool for mapping the research landscape and identifying trends within a specific domain (Boros et al., 2024; Lal et al., 2023; Ruwona & Scherm, 2022; Yan et al., 2020; Yuan & Sun, 2022). Plant pathological expertise can gain insights into the development and diffusion of knowledge in precision agriculture and plant pathology by analyzing publication patterns, citation metrics, and keyword co-occurrence in databases such as Scopus. This study leverages bibliometric methods to explore the global trends in agricultural precision within plant pathology, aiming to identify key research hubs, influential authors, and emerging themes. The findings provide a comprehensive overview of the

current state of research and highlight the potential directions for future studies in this interdisciplinary field.

## 2. Materials and Methods

### 2.1. Data Collection

The data for this bibliometric study were retrieved from the Scopus database, which has about 300 articles (Figure 2), chosen for its comprehensive coverage of peer-reviewed scientific, technical, and medical literature. The search

strategy focused on articles, reviews, and conference papers published from 2010 to 2024, containing keywords: "precision agriculture", "smart farming", "sensor", "computer vision,"- and "plant pathology". Boolean operators and wildcard characters were employed to ensure a thorough search encompassing all relevant terms and their variations. The search query was structured to include terms such as "precision farming," "plant disease management," and "agricultural technology" (Figure 1)

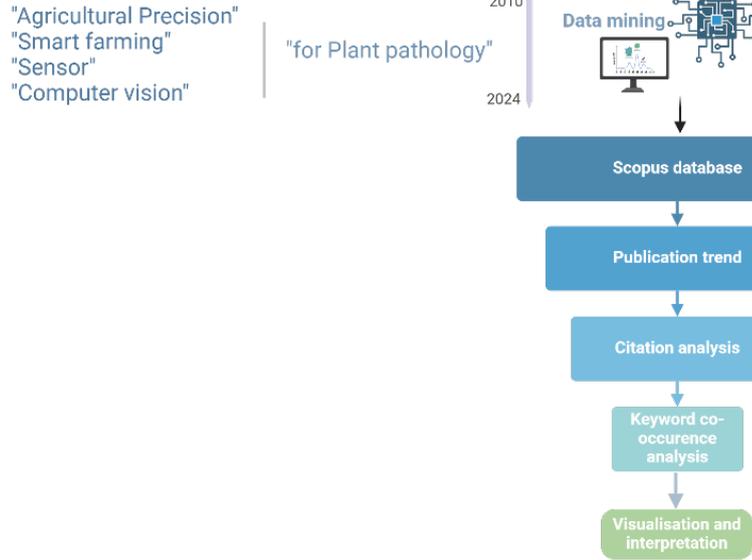


Figure 1. Illustration of bibliometric analysis workflow.

D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X						
1	Year	Source	Publ. no.	Abstracts	Citations	DOI	Year	Source	Publ. no.	Abstracts	Citations	DOI	Year	Source	Publ. no.	Abstracts	Citations	DOI	Year	Source	Publ. no.	Abstracts	Citations			
2	2024	Eurasip Journal on Image and Video Processing	21	11932024.9.00	Article	10.1109/2384-0224-001819-9	2024	11932024.9.00	Article	10.1109/2384-0224-001819-9	2024	11932024.9.00	Article	10.1109/2384-0224-001819-9	2024	11932024.9.00	Article	10.1109/2384-0224-001819-9	2024	11932024.9.00	Article	10.1109/2384-0224-001819-9	2024	11932024.9.00	Article	10.1109/2384-0224-001819-9
3	2024	Applications on Plant and Soils Sciences	33	11932024.9.00	Review	10.1002/aps.11659	2024	11932024.9.00	Review	10.1002/aps.11659	2024	11932024.9.00	Review	10.1002/aps.11659	2024	11932024.9.00	Review	10.1002/aps.11659	2024	11932024.9.00	Review	10.1002/aps.11659	2024	11932024.9.00	Review	10.1002/aps.11659
4	2024	Deakin Brief	38	11932024.9.00	Case Paper	10.1008/ab.2024.101713	2024	11932024.9.00	Case Paper	10.1008/ab.2024.101713	2024	11932024.9.00	Case Paper	10.1008/ab.2024.101713	2024	11932024.9.00	Case Paper	10.1008/ab.2024.101713	2024	11932024.9.00	Case Paper	10.1008/ab.2024.101713	2024	11932024.9.00	Case Paper	10.1008/ab.2024.101713
5	2024	Photographia	39	11932024.9.00	Article	10.1008/PH.2024.03-23-0315-KC	2024	11932024.9.00	Article	10.1008/PH.2024.03-23-0315-KC	2024	11932024.9.00	Article	10.1008/PH.2024.03-23-0315-KC	2024	11932024.9.00	Article	10.1008/PH.2024.03-23-0315-KC	2024	11932024.9.00	Article	10.1008/PH.2024.03-23-0315-KC	2024	11932024.9.00	Article	10.1008/PH.2024.03-23-0315-KC
6	2024	Multimedia Tools and Applications	42	11932024.9.00	Article	10.1007/978-3-0313-7183-7_10	2024	11932024.9.00	Article	10.1007/978-3-0313-7183-7_10	2024	11932024.9.00	Article	10.1007/978-3-0313-7183-7_10	2024	11932024.9.00	Article	10.1007/978-3-0313-7183-7_10	2024	11932024.9.00	Article	10.1007/978-3-0313-7183-7_10	2024	11932024.9.00	Article	10.1007/978-3-0313-7183-7_10
7	2024	Engineering, Technology and Applied Science Research	46	11932024.9.00	Article	10.1008/etars.2024.101713	2024	11932024.9.00	Article	10.1008/etars.2024.101713	2024	11932024.9.00	Article	10.1008/etars.2024.101713	2024	11932024.9.00	Article	10.1008/etars.2024.101713	2024	11932024.9.00	Article	10.1008/etars.2024.101713	2024	11932024.9.00	Article	10.1008/etars.2024.101713
8	2024	Applications on Plant and Soils Sciences	47	11932024.9.00	Article	10.1002/aps.11660	2024	11932024.9.00	Article	10.1002/aps.11660	2024	11932024.9.00	Article	10.1002/aps.11660	2024	11932024.9.00	Article	10.1002/aps.11660	2024	11932024.9.00	Article	10.1002/aps.11660	2024	11932024.9.00	Article	10.1002/aps.11660
9	2024	2nd International Conference on Intelligent Cyber Physical Systems and Internet of Things, ICIPSI 2024	48	11932024.9.00	Conference Paper	10.1008/ICIPSI.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICIPSI.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICIPSI.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICIPSI.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICIPSI.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICIPSI.2024.101713
10	2024	Sensors	49	11932024.9.00	Article	10.3390/s24081019	2024	11932024.9.00	Article	10.3390/s24081019	2024	11932024.9.00	Article	10.3390/s24081019	2024	11932024.9.00	Article	10.3390/s24081019	2024	11932024.9.00	Article	10.3390/s24081019	2024	11932024.9.00	Article	10.3390/s24081019
11	2024	Proceedings - 2024 4th International Conference on Technology Enhanced Learning and Higher Education, ICHL 2024	50	11932024.9.00	Conference Paper	10.1008/ICHEL.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICHEL.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICHEL.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICHEL.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICHEL.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICHEL.2024.101713
12	2024	2024 IEEE 30th International Conference on Telecommunications, ICT 2024	51	11932024.9.00	Conference Paper	10.1008/ICT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICT.2024.101713
13	2024	Lecture Notes in Networks and Systems	52	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_40	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_40	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_40	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_40	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_40	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_40
14	2024	Communications in Computer and Information Science	53	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_49	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_49	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_49	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_49	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_49	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_49
15	2024	Scientific Reports	54	11932024.9.00	Article	10.1038/s41598-024-64801-8	2024	11932024.9.00	Article	10.1038/s41598-024-64801-8	2024	11932024.9.00	Article	10.1038/s41598-024-64801-8	2024	11932024.9.00	Article	10.1038/s41598-024-64801-8	2024	11932024.9.00	Article	10.1038/s41598-024-64801-8	2024	11932024.9.00	Article	10.1038/s41598-024-64801-8
16	2024	Communications in Computer and Information Science	55	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_8	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_8	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_8	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_8	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_8	2024	11932024.9.00	Conference Paper	10.1007/978-3-0314-6436-6_8
17	2024	Computers	56	11932024.9.00	Article	10.3390/computers9050196	2024	11932024.9.00	Article	10.3390/computers9050196	2024	11932024.9.00	Article	10.3390/computers9050196	2024	11932024.9.00	Article	10.3390/computers9050196	2024	11932024.9.00	Article	10.3390/computers9050196	2024	11932024.9.00	Article	10.3390/computers9050196
18	2024	Proceedings - International Conference on Computing, Power, and Communication Technology	57	11932024.9.00	Conference Paper	10.1008/ICPCT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICPCT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICPCT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICPCT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICPCT.2024.101713	2024	11932024.9.00	Conference Paper	10.1008/ICPCT.2024.101713
19	2023	Proceedings of the 3rd International Conference on Artificial Intelligence and Smart Energy, ICISE 2023	17	11932024.9.00	Conference Paper	10.1008/ICISE.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ICISE.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ICISE.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ICISE.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ICISE.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ICISE.2023.101713
20	2023	Ecological Informatics	18	11932024.9.00	Article	10.1008/ecinf.2023.101713	2023	11932024.9.00	Article	10.1008/ecinf.2023.101713	2023	11932024.9.00	Article	10.1008/ecinf.2023.101713	2023	11932024.9.00	Article	10.1008/ecinf.2023.101713	2023	11932024.9.00	Article	10.1008/ecinf.2023.101713	2023	11932024.9.00	Article	10.1008/ecinf.2023.101713
21	2023	Advances in Data Science	27	11932024.9.00	Review	10.1008/ads.2023.101713	2023	11932024.9.00	Review	10.1008/ads.2023.101713	2023	11932024.9.00	Review	10.1008/ads.2023.101713	2023	11932024.9.00	Review	10.1008/ads.2023.101713	2023	11932024.9.00	Review	10.1008/ads.2023.101713	2023	11932024.9.00	Review	10.1008/ads.2023.101713
22	2023	Deakin Brief	28	11932024.9.00	Case Paper	10.1008/ab.2023.101713	2023	11932024.9.00	Case Paper	10.1008/ab.2023.101713	2023	11932024.9.00	Case Paper	10.1008/ab.2023.101713	2023	11932024.9.00	Case Paper	10.1008/ab.2023.101713	2023	11932024.9.00	Case Paper	10.1008/ab.2023.101713	2023	11932024.9.00	Case Paper	10.1008/ab.2023.101713
23	2023	Frontiers in Plant Science	29	11932024.9.00	Review	10.3389/fpls.2023.1224710	2023	11932024.9.00	Review	10.3389/fpls.2023.1224710	2023	11932024.9.00	Review	10.3389/fpls.2023.1224710	2023	11932024.9.00	Review	10.3389/fpls.2023.1224710	2023	11932024.9.00	Review	10.3389/fpls.2023.1224710	2023	11932024.9.00	Review	10.3389/fpls.2023.1224710
24	2023	Tamkang University	36	11932024.9.00	Article	10.1008/tu.2023.101713	2023	11932024.9.00	Article	10.1008/tu.2023.101713	2023	11932024.9.00	Article	10.1008/tu.2023.101713	2023	11932024.9.00	Article	10.1008/tu.2023.101713	2023	11932024.9.00	Article	10.1008/tu.2023.101713	2023	11932024.9.00	Article	10.1008/tu.2023.101713
25	2023	2023 IEEE Region 10 Symposium, TENSYM 2023	40	11932024.9.00	Conference Paper	10.1008/TENSYM.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/TENSYM.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/TENSYM.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/TENSYM.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/TENSYM.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/TENSYM.2023.101713
26	2023	Sensors	43	11932024.9.00	Article	10.3390/s23042712	2023	11932024.9.00	Article	10.3390/s23042712	2023	11932024.9.00	Article	10.3390/s23042712	2023	11932024.9.00	Article	10.3390/s23042712	2023	11932024.9.00	Article	10.3390/s23042712	2023	11932024.9.00	Article	10.3390/s23042712
27	2023	Machine Intelligence, Big Data Analytics, and AI in Image Processing, Practical Applications	44	11932024.9.00	Book Chapter	10.1007/978-3-0313-7183-7_10	2023	11932024.9.00	Book Chapter	10.1007/978-3-0313-7183-7_10	2023	11932024.9.00	Book Chapter	10.1007/978-3-0313-7183-7_10	2023	11932024.9.00	Book Chapter	10.1007/978-3-0313-7183-7_10	2023	11932024.9.00	Book Chapter	10.1007/978-3-0313-7183-7_10	2023	11932024.9.00	Book Chapter	10.1007/978-3-0313-7183-7_10
28	2023	2023 International Conference on Evolutionary Algorithms and Soft Computing Techniques, ISECS 2023	58	11932024.9.00	Conference Paper	10.1008/ISECS.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ISECS.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ISECS.2023.101713	2023	11932024.9.00	Conference Paper	10.1008/ISECS.2023.101713	2023	11932024.9.0						

facilitating the visualization and mapping of bibliographic data. The following analyses were conducted:

- a. Publication trends: The temporal distribution of publications was analysed to identify trends and growth patterns in precision agriculture in plant pathology.
- b. Authorship and collaboration networks: Co-authorship networks were mapped to identify the domain's key researchers, research groups, and collaborative networks.
- c. Citation analysis: Citation metrics were calculated to determine the most influential articles, authors, and journals. Highly cited papers were further analysed to understand their impact on the field.
- d. Keyword co-occurrence analysis: Keywords were analysed to identify prevalent themes and emerging topics. Co-occurrence networks were generated to visualize the relationships between key terms and concepts.
- e. Visualization and interpretation

The results of the bibliometric analysis were visualized using network maps, heat maps, and trend graphs. These visualizations provided a clear representation of the data, facilitating the identification of significant patterns and relationships. The findings were interpreted in the context of global research trends, technological advancements, and the evolving challenges in plant pathology.

**2.4. Limitations**

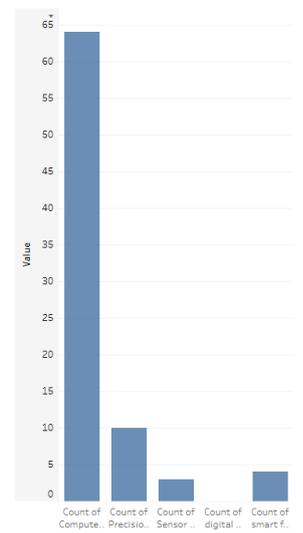
While the Scopus database offers extensive coverage, it may not capture all relevant literature, particularly non-English publications and regional journals. Additionally, the reliance on bibliometric indicators such as citation counts may introduce biases related to publication and citation practices. These limitations were considered in interpreting the results and recommendations for future research. 40% of the total references (300 raw articles) obtained from data mining (Figure 2) were elected (Figure 3, Figure 4, & Table 1) and laid into references, but we acknowledged that this article underlines further questions will be accessed at the link provided and by email to coauthor.

**3. Results**

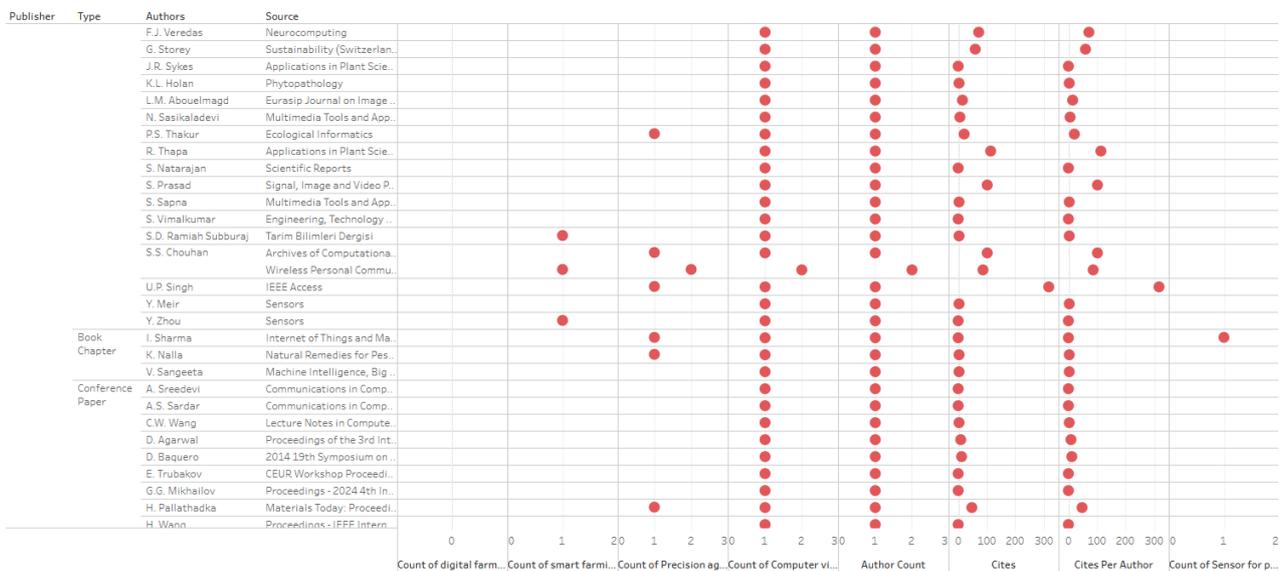
The data presented in this chart reflects research interests and trends within the smart farming domain as applied to plant pathology. The dominance of computation-based techniques indicates that integrating advanced computational methods into plant pathology is a significant research focus area. This might include machine learning, data analytics, and modelling techniques.

The other categories, although cited less frequently, are still crucial. Precision agriculture and sensor technologies represent the growing use of precise and efficient methods to enhance farming practices. Digital and smart farming practices, while not as heavily cited, are indicative of the ongoing exploration of digital transformation in agriculture.

This information can guide researchers by highlighting current trends and potentially under-explored areas that might benefit from further investigation. It can also help identify gaps in the literature where additional research could significantly impact.



**Figure 3.** Number of articles cited every year.



**Figure 4.** Number of sources and authors of precision of agriculture for plant pathology worldwide from 2010 to 2024.

**Table 1.** Selected articles on plant pathology in smart, digital, and precision agriculture 2010–2024.

Authors	Title	Type	DOI	Reference
G. Irmak	A Novel Approach for Tomato Leaf Disease Classification with Deep Convolutional Neural Networks	Article	10.15832/ankutbd.1332675	(Irmak & Saygili, 2023)
Y. Zhou	Few-Shot Image Classification of Crop Diseases Based on Vision–Language Models	Article	10.3390/s24186109	(Zhou et al., 2024)
D. Murtaza	Efficient Convolutional Neural Network (CNN) based Architecture for the Diagnosis of Foliar Pathologies in Potato Crops	Conference Paper	10.1109/KHI-HTC6076.0.2024.10482368	(Murtaza et al., 2024)
M. Jung	Construction of deep learning-based disease detection model in plants	Article	10.1038/s41598-023-34549-2	(Jung et al., 2023)
S.D. Ramiah Subburaj	Transfer Learning based Image Classification of Diseased Tomato Leaves with Optimal Fine-Tuning combined with Heat Map Visualization	Article	10.15832/ankutbd.1230265	(Subburaj et al., 2023)
A. Kumar	Machine Intelligence, Big Data Analytics, and IoT in Image Processing: Practical Applications	Book	10.1002/9781119865513	(A. Kumar et al., 2023)
P. Nancy	Deep Learning and Machine Learning Based Efficient Framework for Image Based Plant Disease Classification and Detection	Conference Paper	10.1109/ICACTA5448.8.2022.9753623	(Nancy et al., 2022)
S.S. Chouhan	Automated Plant Leaf Disease Detection and Classification Using Fuzzy Based Function Network	Article	10.1007/s11277-021-08734-3	(Chouhan et al., 2021)
NA	Expression of Concern: Smart Agriculture using IoT for Plant Pathology and Task Automation (2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS) DOI: 10.1109/ICACCS51430.2021.9442047)	Erratum	10.1109/ICACCS5143.0.2021.10702961	(R. L. R. Singh et al., 2021a)
R.L.R. Singh	Smart Agriculture using IoT for Plant Pathology and Task Automation	Conference Paper	10.1109/ICACCS5143.0.2021.9442047	(R. L. R. Singh et al., 2021b)
S. Verma	Recent advancements in multimedia big data computing for IoT applications in precision agriculture: Opportunities, issues, and challenges	Book Chapter	10.1007/978-981-13-8759-3_15	(Verma et al., 2020)
K.H. Kim	Smart plant disease management using agrometeorological big data	Article	10.5423/RPD.2020.26.3.121	(Kim & Lee, 2020)
Y. Ampatzidis	iPathology: Robotic applications and management of plants and plant diseases	Review	10.3390/s9061010	(Ampatzidis et al., 2017)
S. Ameer Basha	Robotics in plant diseases diagnosis and management	Book Chapter	-	(Basha et al., 2024)
A. Saletnik	Raman Method in Identification of Species and Varieties, Assessment of Plant Maturity and Crop Quality—A Review	Review	10.3390/molecules27144454	(Saletnik et al., 2022)
S. Sampathkumar	An Automated Crop and Plant Disease Identification Scheme Using Cognitive Fuzzy C-Means Algorithm	Article	10.1080/03772063.2020.1780163	(Sampathkumar & Rajeswari, 2022)

Authors	Title	Type	DOI	Reference
J. Ruwona	Sensing and imaging of plant disease through the lens of science mapping	Article	10.1007/s40858-021-00478-6	(Ruwona & Scherm, 2022)
A.C. Hampf	Biotic Yield Losses in the Southern Amazon, Brazil: Making Use of Smartphone-Assisted Plant Disease Diagnosis Data	Article	10.3389/fpls.2021.621168	(Hampf et al., 2021)
A.K. Chakravarthy	Innovative pest management approaches for the 21st century: Harnessing automated unmanned technologies	Book	10.1007/978-981-15-0794-6	(Chakravarthy, 2020)
S. Thite	Empowering agricultural research: A comprehensive custard apple (Annona squamosa) disease dataset for precise detection	Data Paper	10.1016/j.dib.2024.110078	(Thite et al., 2024)
P. Rawat	Apple Leaf Disease Detection Using Transfer Learning	Conference Paper	10.1109/ICICACS605.21.2024.10498746	(Rawat & Singh, 2024)
S. Vats	Leveraging Pre-trained Deep Learning Models for Orange Leaf Disease Classification	Conference Paper	10.1109/12CT6123.2024.10544067	(Vats et al., 2024)
W. Ullah	Efficient identification and classification of apple leaf diseases using lightweight vision transformer (VIT)	Article	10.1007/s43621-024-00307-1	(Ullah et al., 2024)
D. Upadhyay	Advancing Citrus Disease Diagnosis: Application of EfficientNetB3 for Precise Classification of Orange Tree Pathologies	Conference Paper	10.1109/12ETCS6102.2.2024.10543447	(Upadhyay, Manwal, Kukreja, et al., 2024)
S. Chattopadhyay	Leveraging Deep Learning's Potential: A CNN and LSTM Network-Based Severity Classification of Mustard Downy Mildew	Conference Paper	10.1109/12PCT6009.0.2024.10486277	(Chattopadhyay et al., 2024)
D. Upadhyay	Brassica Black Rot Severity Levels classification based on Multimodal Convolutional Neural Networks and Support Vector Machines	Conference Paper	10.1109/12PCT6009.0.2024.10486264	(Upadhyay et al., 2024)
D. Yaswanth	Plant Leaf Disease Detection Using Transfer Learning Approach	Conference Paper	10.1109/SCECS614.02.2024.10482053	(Yaswanth et al., 2024)
S. Hashemifar	Deep Identification of Plant Diseases	Conference Paper	10.1109/AISP61396.2024.10475267	(Hashemifar & Zakari-Nasrabadi, 2024)
X. Ma	ERCP-Net: a channel extension residual structure and adaptive channel attention mechanism for plant leaf disease classification network	Article	10.1038/s41598-024-54287-3	(Ma et al., 2024)
S. John	Integration of Automated Grabcut Algorithm With Deeplabv3+ To Enhance Image Segmentation For Accurate Leaf Disease Detection and Classification	Article	nan	(John & Rose, 2024)
V. Kant	Automated Corn Leaf Disease Diagnosis using ResNet-based Convolutional Neural Network	Conference Paper	10.1109/12oIC162503.2024.10696710	(Kant, 2024)
A.N. Shukla	Agricultural AI Alliance: Federated Learning CNNs for Papaya Leaf Disease Detection	Conference Paper	10.1109/InC460750.2024.10649396	(Shukla et al., 2024)
S. Sahni	New advances in crop disease management	Book	nan	(Sahni et al., 2024)
S. Mittal	InceptionResNetV2 and KNN-Based Detection of Yellow Vein Mosaic Virus in Okra	Conference Paper	10.1007/978-981-97-3817-5_31	(Mittal et al., 2024)

Authors	Title	Type	DOI	Reference	Authors	Title	Type	DOI	Reference
Yashu	Enhancing Disease Severity Classification: Unveiling the Complexity of Sugar Maple Tar Spot with CNN-GAN Framework	Conference Paper	10.1109/1NCET61516.2024.10593314	(Yashu et al., 2024)	B. Biswas	Multilayer Convolutional Neural Network Based Approach to Detect Apple Foliar Disease	Conference Paper	10.1109/1NOCON57975.2023.10101125	(Biswas & Yadav, 2023)
H. Sharma	Plant AI in Agriculture: Innovative Approaches to Sunflower Leaf Disease Detection with Federated Learning CNNs	Conference Paper	10.1109/1NCET61516.2024.10592966	(Sharma et al., 2024)	S. Vats	Federated Learning CNN's in Agriculture: Unveiling Disease Severity Analysis of Java Plum Leaf's	Conference Paper	10.1109/1CUBEA58933.2023.10392276	(Vats et al., 2023)
S.S. Puranik	MobileNetV3 for Mango Leaf Disease Detection: An efficient Deep Learning Approach for Precision Agriculture	Conference Paper	10.1109/1NCET61516.2024.10593318	(Puranik et al., 2024)	A. Chaudhari	Plant Pathology Detection for Massive Heterogeneous Data Using Deep Learning	Conference Paper	10.1109/1CCNT56998.2023.10307170	(Chaudhari et al., 2023)
D. Banerjee	Precision in Plant Pathology: A Hybrid Model Approach for BYDV Syndrome Degrees	Conference Paper	10.1109/1NCET61516.2024.10593415	(Banerjee et al., 2024)	H. Pallathadka	Application of machine learning techniques in rice leaf disease detection	Conference Paper	10.1016/j.matpr.2021.11.398	(Pallathadka et al., 2022)
P.P. Singh	A CNN Model Based Approach for Disease Detection in Mango Plant Leaves	Conference Paper	10.1007/978-981-97-3292-0_27	(P. P. Singh et al., 2024)	T.H.H. Aldhyani	Leaf Pathology Detection in Potato and Pepper Bell Plant using Convolutional Neural Networks	Conference Paper	10.1109/1CCES54183.2022.9835735	(Aldhyani et al., 2022)
V. Kumar	Hybrid CNN & Random Forest Model for Effective Marigold Leaf Disease Diagnosis	Conference Paper	10.1109/1CEMPS60684.2024.10559285	(V. Kumar et al., 2024)	P.L. Kashyap	New Horizons in Wheat and Barley Research: Crop Protection and Resource Management	Book	10.1007/978-981-16-4134-3	(Kashyap et al., 2022)
A. Kaur	Optimized Tomato Rot Disease Severity Profiling: A Hybrid CNN-Random Forest Algorithm for Five-Tier Categorization	Conference Paper	10.1109/12CT61223.2024.10544233	(Kaur, Kukreja, Tiwari, et al., 2024)	V.P. Kour	PlantaeK: A Leaf Database of Native Plants of Jammu and Kashmir	Conference Paper	10.1007/978-981-16-8248-3_29	(Kour & Arora, 2022)
A.P.S. Yadav	Advanced Deep Learning Approaches: Utilizing VGG16, VGG19, and ResNet Architectures for Enhanced Grapevine Disease Detection	Conference Paper	10.1109/1CRIT061523.2024.10522276	(Yadav et al., 2024)	M. Beyer	Enhancing septoria leaf blotch forecasts in winter wheat I: the effect of temperature on the temporal distance between critical rainfall periods and the breaking of the control threshold	Article	10.1007/s41348-021-00553-9	(Beyer, Pallez-Barthel, et al., 2022)
M. Naimuzza man	Plant growth–promoting fungi in plants: Insights from stress tolerance mechanism	Book Chapter	10.1016/B978-0-443-13193-6.00023-3	(Naimuzzaman et al., 2024)	M. Beyer	Enhancing septoria leaf blotch forecasts in winter wheat II: model architecture and validation results	Article	10.1007/s41348-021-00554-8	(Beyer, Marozsak, et al., 2022)
N. Thapliyal	Diagnosis of Plant Infection for Optimised Automatic Health Monitoring System Using Vision Transformer Models	Conference Paper	10.1109/12PCT60090.2024.10486329	(Thapliyal et al., 2024)	K.E. Cholachgudda	Design of a Multispectral and Thermal Data Acquisition System for High-Throughput Phenotyping of Plant Pathology	Conference Paper	10.1109/1CONECCT55679.2022.9865773	(Cholachgudda et al., 2022)
M. Bala	Review—Unveiling the Power of Deep Learning in Plant Pathology: A Review on Leaf Disease Detection	Review	10.1149/2162-8777/ad3981	(Bala & Bansal, 2024)	I. Ul Haq	Phytopathometry: A Transdisciplinary Concept	Book Chapter	10.1007/978-981-19-5896-0_1	(Ul Haq & Ijaz, 2022)
A. Kaur	Towards Sustainable Mango Cultivation: Automated Severity Classification of Mango Rust Disease using CNN-SVM	Conference Paper	10.1109/1CAECT60202.2024.10469170	(Kaur, Kukreja, S, et al., 2024)	Y. Iftikhar	Hyperspectral Imaging Through Spatial and Spectral Sensors for Phytopathometry	Book Chapter	10.1007/978-981-19-5896-0_5	(Iftikhar et al., 2022)
P.S. Thakur	Vision transformer meets convolutional neural network for plant disease classification	Article	10.1016/j.iece.2023.102245	(Thakur et al., 2023)	M. Jeger	Global challenges facing plant pathology: multidisciplinary approaches to meet the food security and environmental challenges in the mid-twenty-first century	Review	10.1186/s41370-021-00042-x	(Jeger et al., 2021)
Z. Salman	Crop-saving with AI: latest trends in deep learning techniques for plant pathology	Review	10.3389/fpls.2023.1224709	(Salman et al., 2023)	F. Calamita	Early identification of root rot disease by using hyperspectral reflectance: the case of pathosystem grapevine/armillaria	Article	10.3390/rs13132436	(Calamita et al., 2021)
H. Slimani	Drone-Assisted Plant Disease Identification Using Artificial Intelligence: A Critical Review	Review	10.12785/1JCDS/140112	(Slimani et al., 2023)	I. Fiaccadori	Spectroscopic detection and monitoring of plant diseases and stress: principles, case studies on fruit and vegetable crops, and perspectives	Article	10.12871/0021857202204	(Fiaccadori & Cotrozzi, 2022)
V. Jindal	Adopting Federated Learning and CNN for Advanced Plant Pathology: A Case of Red Globe Grape Leaf Diseases Dissecting Severity	Conference Paper	10.1109/ASIANCON58793.2023.10270034	(Jindal et al., 2023)	I. Sharma	Plant Disease Detection Using Image Sensors: A Step Towards Precision Agriculture	Book Chapter	nan	(Sharma et al., 2021)
A. Sulaiman	Sustainable Apple Disease Management Using an Intelligent Fine-Tuned Transfer Learning-Based Model	Article	10.3390/su151713228	(Sulaiman et al., 2023)	S.S. Chouhan	Applications of Computer Vision in Plant Pathology: A Survey	Article	10.1007/s11831-019-09324-0	(Chouhan et al., 2020)
J. Su	Holistic Self-Distillation with the Squeeze and Excitation Network for Fine-grained Plant Pathology Classification	Conference Paper	10.23919/FUSION5260.2023.10224184	(Su et al., 2023)	M. Kerkech	VddNet: Vine disease detection network based on multispectral images and depth map	Article	10.3390/rs12203305	(Kerkech et al., 2020)

Authors	Title	Type	DOI	Reference
S.S. Chouhan	Web Facilitated Anthracnose Disease Segmentation from the Leaf of Mango Tree Using Radial Basis Function (RBF) Neural Network	Article	10.1007/s1277-020-07279-1	(Chouhan et al., 2019, 2020a, 2020b, 2021)
L. Aversano	Tomato diseases Classification Based on VGG and Transfer Learning	Conference Paper	10.1109/MetroAgriFo150201.2020.9277626	(Aversano et al., 2020)
S. Verma	Recent advancements in multimedia big data computing for IoT applications in precision agriculture: Opportunities, issues, and challenges	Book Chapter	10.1007/978-981-13-8759-3_15	(Verma et al., 2020)
G. Smagghe	Entomovectoring for precision biocontrol and enhanced pollination of crops	Book	10.1007/978-3-030-18917-4	(Smagghe et al., 2020)
T. Pham	Plant leaf disease classification based on feature selection and deep neural network	Book Chapter	10.1016/B978-0-12-823014-5.00010-7	(Pham & Dao, 2021)
A.M. Abdu	Quantification and Localisation of Individual Leaf Disease Lesion for Grading Severity of Late Blight	Conference Paper	10.1088/1757-899X/884/1/012074	(Abdu et al., 2020)
U.P. Singh	Multilayer Convolution Neural Network for the Classification of Mango Leaves Infected by Anthracnose Disease	Article	10.1109/AACCESS.2019.2907383	(P. P. Singh et al., 2024; R. L. R. Singh et al., 2021b; U. P. Singh et al., 2019)
A. Picon	Crop conditional Convolutional Neural Networks for massive multi-crop plant disease classification over cell phone acquired images taken on real field conditions	Article	10.1016/j.compag.2019.105093	(Picon et al., 2019)
K. Loit	Relative performance of MinION (Oxford Nanopore Technologies) versus Sequel (Pacific Biosciences) third-generation sequencing instruments in identification of agricultural and forest fungal pathogens	Article	10.1128/AEM.01368-19	(Loit et al., 2019)
S. Chaudhary	Review: Crop plant disease detection using image processing	Article	nan	(Chaudhari et al., 2023; Chaudhary et al., 2019)
K. Nalla	Applications of computational methods in plant pathology	Book Chapter	10.1016/B978-0-12-819304-4.00021-X	(Nalla et al., 2020)
A.K. Mahlein	Hyperspectral sensors and imaging technologies in phytopathology: State of the art	Review	10.1146/annurev-phyto-080417-050100	26, 48, 98, 99 (A.-K. Mahlein, 2016; A.-K. Mahlein et al., 2012, 2024; A. K. Mahlein et al., 2018)
A. Tamouridou	Spectral identification of disease in weeds using multilayer perceptron with automatic relevance determination	Article	10.3390/s18092770	(Tamouridou et al., 2018)
Y. Ampatzidis	iPathology: Robotic applications and management of plants and plant diseases	Review	10.3390/s1809061010	(Ampatzidis et al., 2017)
S.S. Sannakki	Computational intelligence for pathological issues in precision agriculture	Book Chapter	10.4018/978-1-4666-3994-2.ch043	(Sannakki et al., 2013)
A. Luvisi	Plants with implanted RFID microchips: Traceability and outlook in information management systems	Book Chapter	nan	(Luvisi & Pagano, 2011)

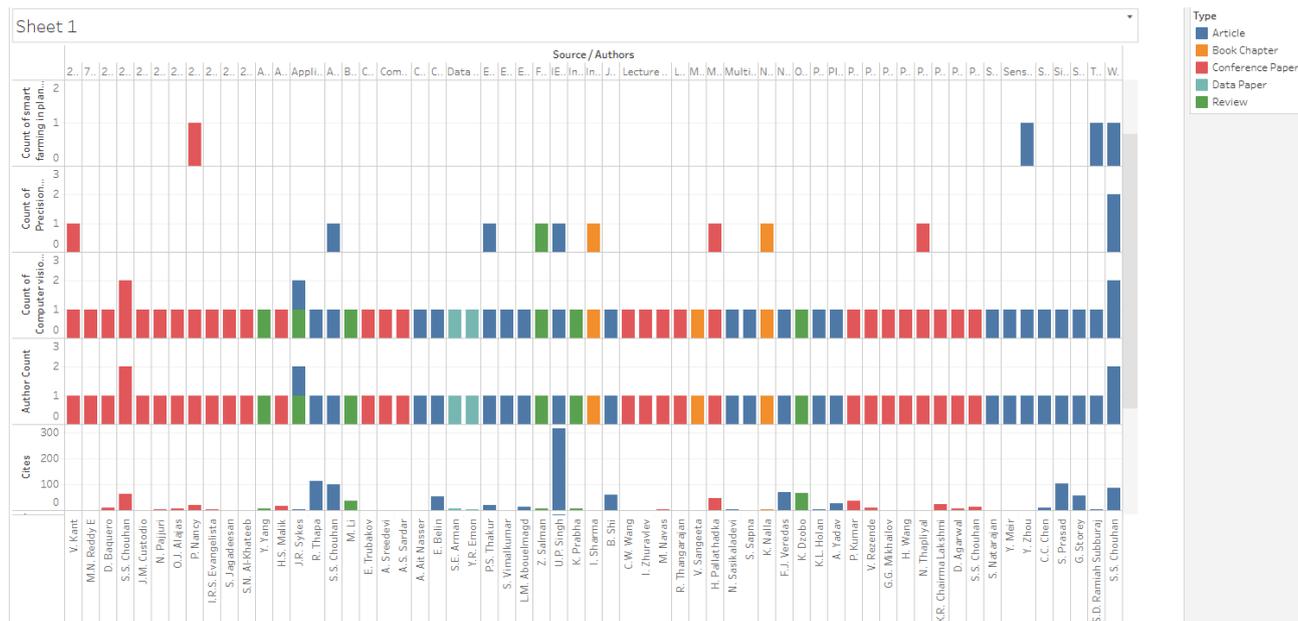
The distribution of citations across these categories highlights current research trends and potential areas for future exploration in smart farming for plant pathology. The prominence of computation-based techniques underscores the importance of leveraging advanced analytical methods to tackle plant pathology challenges. Meanwhile, other categories' moderate and lower citation counts suggest further research and innovation opportunities. This analysis can guide researchers in identifying key areas of impact and gaps in literature.

In-depth academic analysis shows that articles associated with 'Computation-Based Techniques' have the highest number of citations, having a dominant position in this category, with 65 citations, indicating a significant research focus on computational methods in plant pathology. This includes using machine learning, data mining, and predictive modeling to enhance crop disease detection and management. Its implications will be that computational approaches are prevalent and highly impactful, potentially leading to innovative solutions and advancements in precision agriculture. Another is 'precision agriculture' with moderate citations. With around 10 citations, precision agriculture is moderately represented, meaning that this area involves using technologies such as GPS, GIS, and remote sensing to optimize field-level management regarding crop farming. The moderate citation count indicates ongoing interest and application, highlighting the potential for these techniques to improve efficiency and sustainability in farming practices. In Addition, articles related to 'sensor technologies' are likely low interest, having approximately 3 citations, suggesting a narrower research focus compared to computation-based techniques. These technologies are critical for real-time monitoring of environmental conditions and crop health. Despite the lower citation count, developing robust and reliable sensors remains vital for advancing smart farming practices. Furthermore, digital farming practices are less frequently cited. This category encompasses using digital tools and platforms to manage farming operations and data. Similar to sensor technologies cues, smart farming systems retain low citations, with about 5 citations, indicating a budding research area. This category represents the integration of various technologies and approaches to create comprehensive, intelligent farming solutions. It emphasizes the need for holistic systems that can seamlessly manage multiple aspects of farming operations.

The bar chart (Figure 5) presents the number of article citations related to various topics within smart farming in plant pathology. This chart highlights current research trends and identifies areas ripe for future exploration. The high citation count for articles (blue bar) and conference papers (red bar) underscores their critical role in advancing plant pathology through data-driven approaches. Meanwhile, the lower citation counts for sensor technologies, digital farming practices, and smart farming systems suggest opportunities for innovation and development.

By analyzing the citation distribution, researchers can pinpoint influential areas and identify gaps in the literature, guiding future research efforts. This Figure is a

valuable tool for understanding the landscape of smart farming research and its applications in plant pathology.



**Figure 5.** Types of cited articles on various topics within smart farming in plant pathology.

#### 4. Future Direction

In advance, agricultural precision in plant pest and disease management involves several key components. First, there is the issue of model transferability. A notable gap in precision agriculture exists in the adaptability of machine learning models, frequently designed for specific environments or crop types. More research is needed to develop models that can accommodate diverse conditions by integrating a broad array of datasets and algorithms, ensuring accuracy across various agricultural contexts.

Second, we must address interpretable machine learning. The interpretability of machine learning models is another significant challenge. Currently, many models operate as “black boxes,” which can undermine user confidence in their predictions. Research must prioritize the development of explainable models that clarify decision-making processes through feature importance analysis and visualizations, ultimately enhancing user engagement.

Third, the integration of multidisciplinary approaches is essential. Effective disease management in plant pathology requires collaboration among plant pathologists, agronomists, and data scientists. Research should promote interdisciplinary partnerships to address complex plant health challenges, creating frameworks for sharing data, tools, and expertise.

In addition, the impact of climate change on plant diseases warrants further investigation. Understanding how shifting weather patterns affect disease dynamics is crucial for developing adaptive management strategies, including predictive models based on climatic variables and implementing climate-resilient practices.

Lastly, there is a pressing need for global collaboration. Enhancing precision agriculture and plant pathology requires international cooperation and data sharing. Establishing global networks can facilitate knowledge exchange, create comprehensive databases, and

standardize methodologies, thus improving the effectiveness and sustainability of agricultural practices worldwide.

#### 5. Conclusion

This bibliometric analysis, utilizing data retrieved from the Scopus database spanning 2010 to 2024, systematically mapped the global research landscape of precision agriculture as applied to plant pathology. The study identified key research clusters, influential authors, and prevailing thematic trends through quantitative analysis of publication outputs, citation metrics, and keyword co-occurrence.

A significant finding is the marked ascendancy of computational techniques, including machine learning, data analytics, and modelling, as evidenced by the highest citation counts among the analyzed categories. This underscores the increasing integration and impact of advanced computational methods in addressing challenges related to plant disease detection and management. While precision agriculture principles and sensor technologies demonstrate ongoing research interest, areas such as digital farming practices and integrated smart farming systems show comparatively lower citation frequency, indicating potential avenues for future research and innovation.

The analysis highlights several critical areas for future research, including the need to enhance the transferability of machine learning models across diverse agricultural settings, improve the interpretability of complex algorithms to bolster user trust foster greater interdisciplinary collaboration among plant pathologists, agronomists, and data scientists, investigate the impact of climate change on plant disease dynamics and promote global cooperation and data sharing to standardize methodologies and accelerate progress.

In summary, this study confirms the growing importance of precision agriculture technologies in advancing plant pathology research and practice. The findings provide valuable insights for researchers, practitioners, and policymakers, highlighting the dominance of computational approaches and outlining key priorities for future investigation to leverage technological advancements for enhanced crop health, disease management, and sustainable agricultural systems.

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