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EDITORIAL

Special Issue: Digital Plant Pathology for Precision Agriculture

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This Special Issue, published in the Journal of Plant Disease and Protection (JDPD), contains selected papers from the field of Digital Plant Pathology for Precision Agriculture. Digital technologies are ubiquitous and influence our daily living routines. For now over two decades, digital technologies become increasingly more relevant and present themselves in various disciplines of plant pathology and integrated pest management. This domain is a highly dynamic field and innovations in sensors, robotics, artificial intelligence, and data interpretation open new opportunities for detection of plant diseases in an automated and noninvasive way. However, application of available and swiftly developing technology has posed many challenges. Greenhouse and field applications are complex and differ in their study design requirements. Deciding on a sensor type (e.g., thermography, or hyperspectral), a deployment platform (e.g., rovers, UAVs, or satellites), and the appropriate spatial and temporal scale adds to the challenge. This is because the complexity of all pathosystems (host, pathogen, biotic/abiotic environment) is unique and differs in their interactions and symptomology, or lack thereof.

Within this scope, the Special Issue provides a critical look at the past decades of sensor-guided plant pathology in precision agriculture. Relevant aspects of this recent research area are highlighted by three review articles, different methodological studies, proof of concept studies, and original papers. Sophisticated methods to analyze and interpret complex sensor data are necessary in addition to the sensor and platform choice. Modern machine learning—especially deep learning—approaches enable fast and subjective data perusal and identification of probable cohesive parameters during plant–pathogen interactions. However, developed methods often lack trust in performance and reliability in plant protection is needed for real field applications. Furthermore, we still face the challenge that a transfer of models from one system to another is not possible. Therefore, linking biological cause to machine learning features is a crucial task that will bridge the gap between proof of concept to proof of application in Digital Plant Pathology. In the future, research in the field of interpretable machine learning will hopefully allow operators to interact with the algorithm to gain trust in the system and the technology. New robots for the field, artificial machine intelligence, and natural human

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intelligence will define the future of agriculture and plant protection.

Looking at the range of topics addressed, the diversity and interdisciplinary nature of this research area are reflected in this Special Issue.

The *Journal of Plant Diseases and Protection* presents the most recent research on disease identification and quantification from leaf to field scale, sensing of plant–pathogen interactions, and on highly sophisticated sensor data analysis methods. The articles presented as part of the Special Issue were authored by researchers from many countries around the world with diverse scientific background and address the four following areas of research:

1. Sensor–Plant–Pathogen Interactions
   - Disease indicators and detection thresholds for specific sensors in *Digital Plant Pathology*.
   - Sensor and spectral databases for plant disease identification in the field.
   - Evaluated systems for *Digital Plant Pathology*. Validation across and within pathosystems.
2. Machine Learning in *Digital Plant Pathology*
   - New methods for image analysis.
   - Interpretable machine learning: linking biological processes with algorithmic features.
   - Deep learning approaches for plant disease identification.
   - In-field data processing workflows for real-time applications.
3. Robots, UAVs, and satellites for pest and pathogen detection
   - Sensor integration in multi-sensor approaches and processing workflows.
   - Multiscale sensing in plant pathology.
4. *Digital Plant Pathology* for Integrated Disease Management
   - Adoption rates and economic and environmental evaluation of applied *Digital Plant Pathology*.
   - Shaping the *Digital Plant Pathology* infrastructures enable sensor technology.
   - Opinion pieces on perspectives and outlooks in Digital Plant Pathology.

The review and perspectives paper of Kuska et al. provide a critical review of the history of Digital Plant Pathology and touch on how we can shape the future of *Digital Plant Pathology* for *Precision Agriculture* and ensure to keep its promise. This article offers an interesting overview also for researchers which are new in the domain of Digital Plant Pathology. The technical perspective from Shaif et al. gives an overview on wheat rust disease detection techniques to improve early detection of wheat rust potentially resulting in minimized yield losses. The authors address several smart farming technologies, including remote sensing, Internet of things (IoT), machine learning, and deep learning. Apart from the application of digital technologies in field crops, also horticultural crops may benefit from new management practices. This purpose is addressed in the review article by Thangaraj et al. on artificial intelligence in tomato leaf disease detection. The authors provide a critical review on recent work in the field of tomato leaf disease identification, using image processing, machine learning, and deep learning approaches. A very important aspect in this publication is the discussion of the benefit of both public and private datasets to improve the performance of image analysis techniques.

The rise of machine learning, computer vision, and, especially, deep learning techniques has impacted plant disease detection techniques significantly. This is also reflected in the high number of original research articles in this area. The crops and pathosystems covered are from a wide range of relevant production systems like cassava, barley, wheat, brassica chinensis, tomato, strawberry, grape, or even studies addressing multiple host–pathogen systems. All these studies are characterized by their interdisciplinary nature and the cooperation between experts from different disciplines. Reaching high accuracies of prediction in their model's proofs evidence that this is the way of success: integrating knowledge from an array of interfacing disciplines to shape and harness innovative research approaches. This Special Issue and its authors show impressive how interdisciplinary teams work together for solving latest questions in digital plant protection. The elucidated topics, problems, and workflows describe the state of the art in using digital tools for plant pathology. Thus we see this collection as an important contribution for the interdisciplinary coalesce in Digital Plant Pathology and Precision Agriculture.

We, the guest editors are curious, how this dynamic research will evolve, and how the step into practical agriculture will occur successfully. The selected papers included in this Special Issue demonstrate the up-to-dateness of digital technologies for phytopathology and we hope that the content will be useful for a wide audience of scientists, students, agronomists, and people who are interested in new approaches for the detection and identification of plant diseases and their management.