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# THE R2M TOOLBOX: RAPID RISK ASSESSMENT FOR SUPPORTING PLANT DISEASE AND PEST MITIGATION

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The R2M Toolbox (Rapid Risk Assessment for Mitigation) represents an innovative approach to identifying, assessing, and mitigating risks associated with plant diseases and pests. In the context of growing global agricultural challenges, including climate change, global trade, and evolving pest dynamics, the need for a swift, comprehensive, and effective risk assessment tool is paramount. This review explores the components, applications, and efficacy of the R2M Toolbox, emphasizing its relevance to contemporary plant disease management. Case studies and examples from recent literature will illustrate how the R2M Toolbox can enhance decision-making in plant disease and pest management.

Global agriculture is under constant threat from a variety of plant diseases and pests, which can have devastating effects on crop yields, food security, and economies. With the increasing interconnectedness of global trade and climate change influencing pest and pathogen distributions, traditional risk assessment methods are often too slow or not comprehensive enough to address these challenges effectively. The R2M Toolbox offers a solution by providing a rapid, systematic approach to risk assessment that supports timely mitigation strategies (Andersen *et al*., 2019).

## The R2M Toolbox

The R2M Toolbox enables rapid risk assessments for early detection, analysis, and intervention. It integrates diverse data sources like remote sensing and climate models, uses adaptive algorithms to prioritize risks, and provides actionable insights through Decision Support Systems (DSS). Additionally, it includes tools for effective communication and

collaboration among stakeholders, ensuring coordinated responses to plant disease and pest threats. (Andersen Onofre *et al*., 2021a).

## Applications in Plant Disease Management

The R2M Toolbox has been applied in various contexts to address plant diseases. Below are some key examples:

### Wheat Rust Management

Wheat rust, caused by the fungus *Puccinia graminis*, is a significant threat to global wheat production. The R2M Toolbox has been used to monitor the spread of new rust strains, such as the highly virulent Ug99. By integrating climate data, genetic analysis of pathogen populations, and wheat cultivar resistance information, the toolbox helps predict outbreaks and guide the deployment of resistant varieties. Recent studies have shown that using the R2M Toolbox can reduce the economic impact of wheat rust by up to 30% by enabling timely interventions (Buddenhagen *et al.*, 2017).

### Citrus Greening Disease (Huanglongbing)

Citrus greening, or Huanglongbing (HLB), is a severe disease impacting citrus trees, causing significant economic losses. The R2M Toolbox has been effectively used in regions like Florida and Brazil, utilizing real-time data to identify disease hotspots and guide targeted pesticide applications. Advances in remote sensing have improved the toolbox's ability to detect early HLB symptoms, enhancing disease management efforts.

### Banana Fusarium Wilt

*Fusarium* wilt of banana, caused by *Fusarium oxysporum*, is a major global threat to banana production. The R2M Toolbox has been crucial in tracking the spread of Tropical Race 4 (TR4), especially in Southeast Asia. By integrating soil health data, crop rotation, and pathogen monitoring, the toolbox aids farmers in containing the disease. Recent studies from 2023 show that the toolbox has helped slow the spread of TR4 in affected areas (Etherton *et al.*, 2023).

## Network Model of CMD Spread

Environmental conduciveness is just one factor in the spread of Cassava Mosaic Disease (CMD). Dispersal, through infected planting material and viruliferous whiteflies,

also plays a crucial role. We combined the likelihood of these dispersal methods for our simulation experiments and tested various clean seed deployment scenarios. The epidemic model, adapted from Andersen et al. (2019), uses a discrete time network SI (susceptible-infected) Markov chain with modifications. These include within-node disease spread driven by the transmission rate (β) and infection probability based on both transmission and establishment (ε). Additionally, in management scenarios, we account for incomplete recovery at nodes, depending on the proportion of healthy cassava introduced at the season's start.

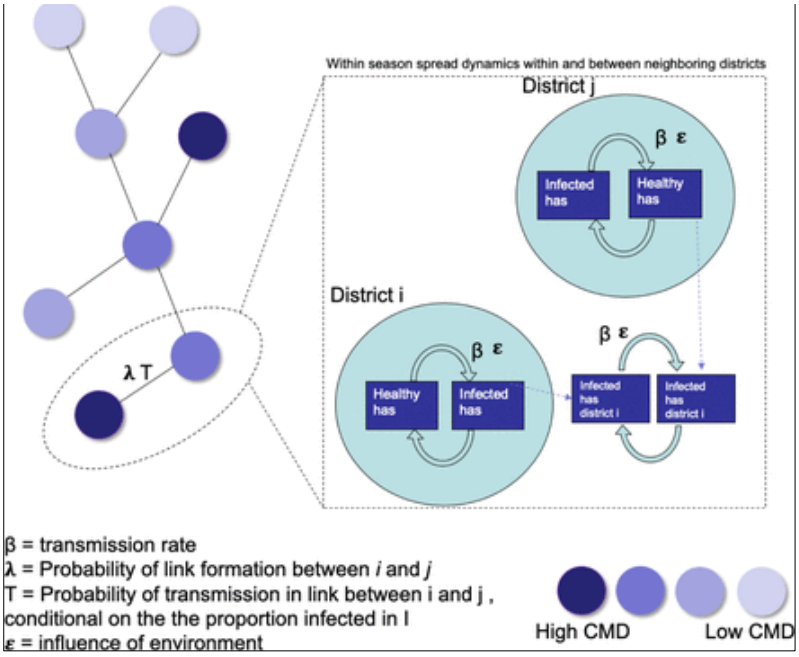


**Fig. 1.** This schematic shows a network metapopulation model for cassava mosaic disease (CMD) spread through seed systems and vectors.

The left side depicts cassava seed trade links at the season's start, where moving infected planting material can introduce CMD to new districts. The right side illustrates within- and between-node spread during the season. Infected material can spread CMD within a district and to adjacent districts, with within-season transmission driven by whiteflies. Seed trade links occur only at the season's start, while within-node spread happens over 10 monthly steps during the season (Source: Andersen Onofre *et al.*, 2024)

## Challenges and Limitations

While the R2M Toolbox offers significant advancements in plant disease management, it faces challenges such as data quality and availability, especially in regions with limited technology. Adoption barriers, including costs, technical expertise, and

resistance to change, can also hinder its effectiveness. Additionally, climate change introduces uncertainties, requiring the toolbox to adapt continuously. Lastly, successful implementation demands interdisciplinary collaboration, which can be difficult to establish and maintain (Nduwimana *et al.*, 2022).

## Future Directions and Innovations

The future of the R2M Toolbox lies in its integration with emerging technologies. Incorporating AI and machine learning could improve predictive accuracy, while advances in remote sensing through satellites and drones could enhance early disease detection. Expanding to a global user network would foster data sharing and best practices. Additionally, integrating the toolbox with breeding programs for climate-resilient crops could help mitigate disease impacts from climate change.

## Conclusion

The R2M Toolbox is a powerful tool for rapid risk assessment and mitigation in the face of evolving plant disease and pest challenges. Its ability to integrate diverse data sources, provide actionable insights, and support collaborative efforts makes it an essential component of modern plant disease management strategies. However, to fully realize its potential, ongoing efforts are needed to address challenges related to data quality, adoption barriers, and the dynamic nature of climate change. By continuing to innovate and expand its applications, the R2M Toolbox can play a crucial role in securing global food security and sustainable agriculture.

## References

Andersen Onofre, K., Delaquis, E., Newby, J., de Haan, S., Thuy, C. T. L., Minato, N., Legg, J., Cuellar, W., Alcala Briseno, R., & Garrett, K. A. (2024). Decision support for managing an invasive pathogen through efficient clean seed systems: Cassava mosaic disease in Southeast Asia. *bioRxiv*, 2024-02.

Andersen, K. F., Buddenhagen, C. E., Rachkara, P., Gibson, R., Kalule, S., Phillips, D., & Garrett, K. A. (2019). Modeling epidemics in seed systems and landscapes to guide management strategies: The case of sweet potato in Northern Uganda. *Phytopathology*, 109(9), 1519-1532.

Buddenhagen, C. E., Xing, Y., Andrade-Piedra, J. L., Forbes, G. A., Kromann, P., Navarrete, I., Thomas-Sharma, S., Choudhury, R. A., Andersen Onofre, K. F., Schulte-Geldermann, E., & Etherton, B. A. (2022). Where to invest project efforts for greater benefit: A framework for management performance mapping with examples for potato seed health. *Phytopathology*, 112(7), 1431-1443.

Etherton, B. A., Choudhury, R. A., Alcalá-Briseño, R. I., Xing, Y., Sulá, A. P., Carrillo, D., Wasielewski, J., Stelinski, L. L., Grogan, K. A., Ballen, F., & Blare, T. (2023). Are avocados toast? A framework to analyze decision-making for emerging epidemics, applied to laurel wilt. Agricultural Systems, 206, 103615.

Nduwimana, I., Sylla, S., Xing, Y., Simbare, A., Niyongere, C., Garrett, K. A., & Bonaventure Omondi, A. (2022). Banana seed exchange networks in Burundi – Linking formal and informal systems. *Outlook on Agriculture*, 51(3), 334-348.

Onofre, K. F. A., Forbes, G. A., Andrade-Piedra, J. L., Buddenhagen, C. E., Fulton, J. C., Gatto, M., Khidesheli, Z., Mdivani, R., Xing, Y., & Garrett, K. A. (2021). An integrated seed health strategy and phytosanitary risk assessment: Potato in the Republic of Georgia. *Agricultural Systems*, 191, 103144.