International research consortium advances wheat disease early warning system for subsistence farmers in Africa and Asia

The State of Food Security and Nutrition in the World 2023[1] estimates that almost 600 million people will be chronically undernourished in 2030, with a significant proportion living in regions of Africa and western Asia. Wheat contributes one-fifth of the global food supply and demand for wheat-based products continues to rise. A major threat to harvests comes from fungal diseases, that can destroy entire wheat crops, severely impacting wheat production in low and lower-middle income countries. Some of the most important of these diseases are caused by the wheat rusts; stem (*Puccinia graminis* f. sp. *tritici*), stripe (*P. striiformis* f. sp. *tritici*) and leaf rust (*P. triticina*), are highly capable of producing millions of spores that can travel in the air up to thousands of kilometres in distance, causing epidemics across international borders.

Vigilance is key….

Effective control of destructive airborne pathogens on susceptible wheat crops depends upon early warning systems that predict disease risk in time to enable farmers to apply fungicides to prevent yield loss.

In a review published recently in *Annual Review of Phytopathology*, Professor Chris Gilligan (Epidemiology & Modelling Group) presents a global perspective of research that has led to the development of sophisticated modelling tools to analyse aerobiological pathways and to forecast invasion risks of airborne pathogens. The review draws on more than a decade of research by his group at the University of Cambridge.

Describing the history of Early Warning Systems for epidemiological predictions in the context of food security, Gilligan explores how models can be used to inform national agencies about the risks of long-distance, transboundary incursion of pathogens, helping agricultural planners and farmers along the dispersal pathways to prepare for and mitigate the risks of wheat rust infection and crop losses.

He describes the development of a flexible modelling framework that integrates multiple data sources and a range of modelling techniques to analyse and predict the risks of wheat rust dispersal and infection at spatial scales extending from tens to hundreds and thousands of kilometres. The framework uses computationally intensive simulations, including a Lagrangian particle dispersion model, an environmental suitability model, and network analysis, to identify characteristic pathways for wheat stem rust transmission across multiple countries and regions.

A research team at the University of Cambridge worked in partnership to develop and pilot an integrated mathematical model for operating early warning systems that can rapidly and reliably inform subsistence farmers on potential outbreaks of pests and diseases. A new programme, Wheat Disease Early Warning and Advisory System (DEWAS), jointly funded through a $7.3 million grant from the Bill & Melinda Gates Foundation and the UK's Foreign, Commonwealth and Development Office, has now made it possible for them to extend this vital service across regions in Sub-Saharan Africa and South Asia.

The Early Warning and Advisory System (EWAS) was originally developed and implemented for wheat rusts in Ethiopia, where it has been estimated that there are over 4–5 million smallholder households who depend on wheat for food or as a source of income[2]. The EWAS has since been adapted and deployed in Nepal and Bangladesh, within South Asia, which is also one of the largest wheat producing regions, accounting for 50.6 M ha, 23% of global wheat production in 2020[3]. Gilligan's review emphasises the importance and strength of transdisciplinary partnerships in developing and using an early warning and advisory system. The wheat rust EWAS involves field surveillance by trained experts who identify new sources of infection, weather-driven dynamic models supported by national and international meteorological agencies and the production and distribution of advisory reports that require agronomic specialists to interpret and communicate risk to growers in near real-time.

A) Susceptible host landscape **B) Pathogen dispersal** **C) Environmental suitability landscape**

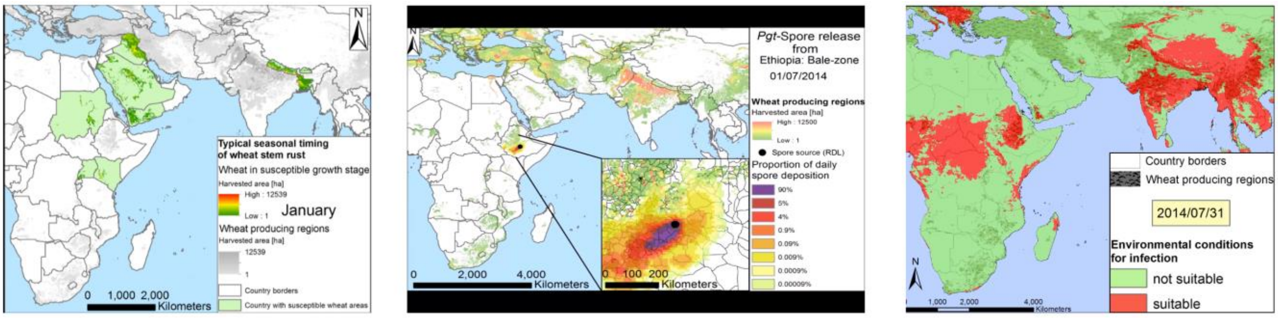

Figure above: Identifying sites at risk of epidemics of stem rust involves the integration of complex dynamics including, A) the wheat crop landscape, (which changes seasonally at approximately monthly timescales); B) the pathogen dispersal landscape over which spores are dispersed (surviving for three to five days in air); C) the environmental suitability landscape for infection at spore landing sites (which changes diurnally).

See publication: Gilligan C. (2024) Developing predictive models and early warning systems for invading pathogens: Wheat rusts. *Annual Review of Phytopathology*, 62:8.1-8.25
doi.org/10.1146/annurev-phyto-121423-041956

Extending surveillance beyond borders

Image credit: J. Smith, University of Cambridge

One of the major challenges in forecasting epidemics of plant pathogens that are capable of long-distance dispersal is to account for sources of infection from countries or regions for which near real-time surveillance data are unavailable.

Automated data collection from on-line sources (‘web-scraping') has been shown to be useful for monitoring outbreaks and spread of human infectious diseases. The use of these methods could be highly advantageous for detecting potential threats from invasive pests when more formal methods of gathering data on the ground are not possible.

Field survey, Nepal 2024: Stripe rust, Puccinia striiformis f. sp. *tritici*. Image credits: T. Mona and J. Smith, University of Cambridge

A study carried out by Jacob Smith (Epidemiology & Modelling Group) and co-authors tested whether web-scaping reports of disease incidence in wheat-producing regions in India and Pakistan (proxy surveys) could be integrated into models with regional weather data to give accurate predictions of wheat-rust spore deposition in crops in neighbouring countries, such as Nepal and Bangladesh. The team compared wheat stripe rust surveillance data gathered by agronomists during a serious outbreak in Nepal in 2020, with data obtained by web-scraping of news outlets in neighbouring countries within the same time frame.

With the use of their web-scraping algorithm, the team were able to demonstrate that west Nepal was exposed to aerially dispersed stripe rust spores that originated from India and Pakistan. The study supports the use of media sampling as an effective alternative where data from ground surveys are not readily available in near real-time. The paper recommends that policymakers promote international cooperation and coordination in monitoring and managing transboundary plant pathogens like wheat rust. Proxy surveys from scraped online news media could be considered as a low-cost, high-coverage complement to near real-time field surveillance for plant disease early warning systems.

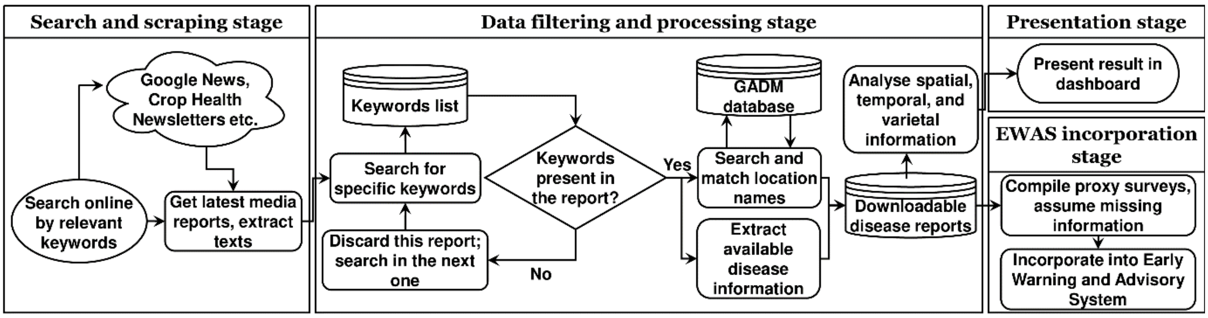

Figure above shows workflow of the scraper tool for media reports of wheat rust infections for retrieving data for the Early Warning and Advisory System (see AsifAlFaisal/project-arrcc: Published version of the ARRCC dashboard. Available at: https://doi.org/10.5281/ zenodo.8024493)

See publication: Smith, J. W., Al Faisal, A., Hodson, D., Baidya, S., Bhatta, M., Thapa, D., Basnet, R., Thurston, W., Krupnik, T.J., Gilligan, C. A. (2024) Advancing crop disease early warning in South Asia by complementing expert surveys with internet media scraping. Climate Resilience and Sustainability; 3:e78. https://doi.org/10.1002/cli2.78

Project funders and partners:

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The wheat rust EWAS involves an international partnership among the University of Cambridge, UK Met Office, International Maize and Wheat Improvement Center (CIMMYT) and national agricultural research institutes and agricultural extension agencies in Ethiopia, Nepal and Bangladesh, with ongoing extension to Kenya, Tanzania, Zambia, Pakistan and Bhutan.

References

[1]FAO, IFAD, UNICEF, WFP and WHO. 2023. *The State of Food Security and Nutrition in the World 2023*. *Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum*. Rome, FAO. https://doi.org/10.4060/cc3017en

[2]Taffesse AS, Dorosh P, Asrat S. 2018. Crop production in Ethiopia: regional patterns and trends. Summary of Ethiopia strategy support program. Technical report. International Food Policy Research Institute, Ethiopian Development Research Institute. https://reliefweb.int/sites/reliefweb.int/files/resources/essprn11.pdf.

[3]FAOSTAT. (2023) Food and agriculture data. Available at: https://www.fao.org/faostat/en/#home

For more information on research projects undertaken by Epidemiology & Modelling Group in the Dept. Plant Sciences, please visit https://www.plantsci.cam.ac.uk/research/groups/epidemiology-and-modelling