Letters

Weather does influence fungal and oomycete crop disease outbreaks, but ProMED-mail reports don't prove it

A comment on Romero *et al*. (2022) 'Humidity and high temperature are important for predicting fungal disease outbreaks worldwide'

In a Letter published in this issue of *New Phytologist*, Romero *et al.* (2022; pp. 1553–1556) analyse ProMED-mail plant disease reports to assess the factors that predict fungal disease outbreaks, concluding that high humidity is the most important determinant. However, close inspection of the same reports reveals that there is no direct mention of high humidity in most of the cases cited by Romero *et al.*, and their conclusions are therefore unsupported.

Farmers around the world fight a ceaseless war against numerous pathogens, pests and weeds. The spread of these organisms has been facilitated by international trade and transport, but there is growing concern that climate change could also increase disease risk and pest impacts (Deutsch *et al.*, 2018; Chaloner *et al.*, 2021). Observational data of pest and pathogen impacts are sparse, leaving researchers to infer climate change effects from biased and incomplete data sets which have often been collected for other purposes (Bebber *et al.*, 2019). One example is an influential paper published in 2004, which extracted information on the factors causing plant diseases from reports on the ProMED-mail online service (Anderson *et al.*, 2004). ProMED-mail was established in 1994 by the International Society for Infectious Diseases, as an online service to identify unusual health events caused by toxins and diseases of humans, animals and plants. For example, on 30 December 2019 ProMED-mail report 20191230.6864153 described an undiagnosed pneumonia in Hubei province, China, from automated translations of a *Finance Sina* article which stated that 'the first patient with unexplained pneumonia that appeared in Wuhan this time came from Wuhan South China seafood market'.

ProMED-mail also reports on plant diseases, providing summaries of news items or academic papers along with background information on the reported disease in a short commentary. Anderson *et al.* (2004) analysed ProMED-mail plant reports for 1996 to 2002 to identify the most significant drivers of disease emergence. They found that weather accounted for 44% of plant disease outbreaks, raising the possibility of a significant climate change effect. In a Letter published in this issue of *New Phytologist*, Romero *et al.* have attempted to replicate the ProMED-mail plant disease analysis, but provide more detail on what weather conditions specifically are cited as the main potential drivers of disease outbreaks. They analysed 264 reports of fungal and oomycete disease outbreaks from 2014 to 2019, and suggest that high humidity is reported as the main driver in 36.4% of cases, high temperature in 17.7% and low temperature in 9.9%. The authors state that the analysis 'demonstrates that climate variables (relative humidity, high and low temperature) are key factors explaining the occurrence of disease outbreaks'.

Given that a previous analysis of ProMED-mail plant disease first reports between 2010 and 2015 found little mention of weather factors (Bebber, 2015), the findings of Romero and colleagues are surprising. In fact, detailed inspection of the reports which Romero and colleagues purport to show a role for high humidity reveals a misinterpretation of the information given in most of those reports. Of the 73 reports flagged as providing evidence for high humidity as a driver of disease outbreaks, only 15 unequivocally support this assertion, with a further 14 giving either partial or unclear support (Supporting Information Table S1). A possible reason for this error is that the authors have conflated the commentary given underneath each ProMED-mail report with the item described in the report itself. Commentaries are written by ProMED editors and give basic details about the diseases mentioned in each report. For example, report 20170713.5171518 describes an outbreak of downy mildew (*Pseudoperonospora cubensis*) in the USA and Canada, taken from articles in *Morning AgClips* and *HortiDaily*. Neither the ProMED-mail reports nor the original sources cite high humidity as the driver of the outbreaks. The original article in *Morning AgClips* states 'Upon detection, growers should use intensive spray programs every 5–7 d, especially if weather conditions are conducive (wet and cool)'. The commentary beneath the report states 'disease development can occur over a wide temperature range under conditions of high humidity'.

In these and other cases, Romero and colleagues have inferred that humidity is the main driver of the disease outbreak. Their logic is as follows: we know that the disease is promoted by high humidity, therefore if the disease occurs then high humidity must have been the main cause. However, high humidity is not the only determinant of disease risk. It is often necessary, but always insufficient. A virulent pathogen, susceptible host and conducive environment are all required. We have no way of telling if weather conditions were particularly humid in these cases, particularly since direct measurements of humidity are not reported. Conditions might always be sufficiently humid and some other factor caused the outbreak in these cases, for example the arrival of a new virulent pathogen population, or a change in crop management. Certainly, neither the reports nor the items they derive from cite humidity as the main cause of disease outbreaks.

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In another example, report number 20140611.2533396 describes outbreaks of late blight of potato (caused by *Phytophthora infestans*) in Nigeria and the UK. The reports are derived from articles in *The Nigerian Observer* and *Farmers Guardian*. The Nigerian case makes no mention of weather in relation to the blight outbreak, while in the UK case an agronomy company suggests that 'the mild, wet winter and spring have created ideal conditions [for the disease]'. Humidity is not mentioned specifically. The driver of the UK outbreak could have been temperature, rainfall, or humidity, or some nonclimatic factor of which the agronomists were unaware.

In some cases, there is slightly more support for the hypothesis of high humidity as the major driver. For example, case 20191208.6829852 describes an onion purple blotch (*Alternaria porri*) outbreak on shallots in India. The original article in the *Times of India* states 'we had continuous downpour almost every day for about a month, leaving the soil soaked and shallots rotting'. Romero and colleagues have inferred that heavy rainfall is associated with high humidity which promotes the disease, but the causal factor in this case is specifically listed as heavy rain, not high humidity.

It is well established that many fungal diseases require high humidity for spore germination and infection of their host plant (Rowlandson *et al.*, 2014). To that extent, Romero and colleague's assertion that humidity is important for predicting fungal disease outbreaks world-wide simply restates existing information on disease biology (which is sometimes supplied in the ProMED-mail commentary). The stronger assertion that high humidity is the major driver in these cases is very poorly supported by the information in the ProMED-mail reports, and their findings are not driven by robust evidence abstracted from the various reports they cite. Plant pathogens cause major losses in agriculture, but their distributions, drivers and impacts remain poorly understood. Collaborative international research programmes, like the Centre for Agriculture and Bioscience International (CABI) Global Burden of Crop Loss (https://croploss.org/) initiative, which collate diverse data sources to build predictive disease impact models, are needed to fill this knowledge gap and enable targeted responses to plant pathogens.

ORCID

Daniel P. Bebber https://orcid.org/0000-0003-4440-1482

Daniel P. Bebber

Department of Biosciences, University of Exeter, Exeter, EX4 4QD, UK
(email: d.bebber@exeter.ac.uk)

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Supporting Information

Additional Supporting Information may be found online in the Supporting Information section at the end of the article.

Table S1 Assessment of role of humidity in disease outbreaks in ProMED-mail reports.

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