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Weather data requirements for disease warning systems

Robert M. Beresford

Plant & Food Research, Auckland, New Zealand

New Zealand has over 30 years' experience developing and implementing weather-based disease warning systems for fruit and vegetable crops. These systems require meteorological data, which can be obtained from a range sources, including: 1) stand-alone weather stations, 2) regional weather station networks, where farmers access the nearest station, 3) regional or national weather station networks with spatial interpolation to provide site-specific data, 4) virtual weather data grids from interpolated or modelled weather data, 5) weather forecast data.

The most commonly used meteorological variables for disease warnings are: 1) temperature (easy to measure), 2) precipitation (easy to measure, but high spatial variability causing local errors, 3) moisture as "leaf" wetness (high spatial variability, limited availability in weather data networks and not recognised by the World Meteorological Organisation) and 4) moisture as relative humidity (RH) (sensors require frequent calibration and errors are common, especially in the 90 and 100% range required for infection by plant pathogens.

Moisture variables (wetness, RH and rainfall) are the most difficult to measure. However, accuracy problems matter less than expected because of the nature of weather events that promote plant diseases. Rain-bearing systems occur as discrete events. Their passage over a location changes the conditions so markedly that sub-regional stations using rainfall, wetness or RH sensors generally detect high risk periods sufficiently accurately.

Disease warning systems aim to reduce use of disease control chemicals (fungicides and bactericides) and improve control. However, they often have low uptake by user groups for a range of reasons. Inaccurate meteorological data is not usually the major reason. More important is accuracy of the underlying risk model and whether a particular cropping context is suitable for a disease warning system. Disease warning systems require the following to achieve improvement in disease control using chemicals:

1. Effective chemicals or other options.
2. Accurate weather based risk model capturing the dependence of disease on meteorological conditions.
3. Computer system to access and process weather data and a platform to deliver warning messages.
4. Frequency of risk events must be low relative to the frequency of fungicide applications in a

standard spray programme. If events are very frequent, there is no opportunity to change spraying practices using warnings.

5. Farmers must have flexibility to modify spraying operations according to weather-based warnings. Action is required within 1 to 2 days of a warning (weather forecasts help).

6. Uptake of warnings requires a driver for reduced spraying, e.g. high chemical and spraying costs, government or industry regulated limits, or market access consequences from chemical residue risks.

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Weather data requirements for disease warning systems: A New Zealand perspective

Dr Robert Beresford, Auckland, New Zealand

Disease Warning systems in New Zealand

In New Zealand, we have been developing and implementing weather-based disease warning systems for more than 30 years.

These have been developed by Plant & Food Research in conjunction with three different providers of meteorological data services:

- HortPlus Ltd (horticulture software development company)
- New Zealand MetService
- National Institute of Water and Atmospheric Research (NIWA).

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Disease warning systems in New Zealand

Develpt period	Host plant	Disease	Pathogen
1986 – 1995	Apple	Scab	*Venturia inaequalis*
1992 – 1995	Apple	Fire blight	*Erwinia amylovora*
1999 – 2004	Onion	Downy mildew	*Peronospora destructor*
2004 – 2005	Potato	Late blight	*Phytophthora infestans*
2000 – 2010	Wine grape	Bunch rot	*Botrytis cinerea*
2011 – 2012	Kiwifruit	Bacterial canker (Psa)	*Pseudomonas syringae* pv. *actinidiae*
2012 – 2015	Apple	Elsinoe leaf and fruit spot	*Elsinoe pyri*
2017 – 2019	Myrtaceae	Myrtle rust	*Austropuccinia psidii*
2015 – 2019	Apple	European canker	*Neonectria ditissima*

New Zealand disease warning systems

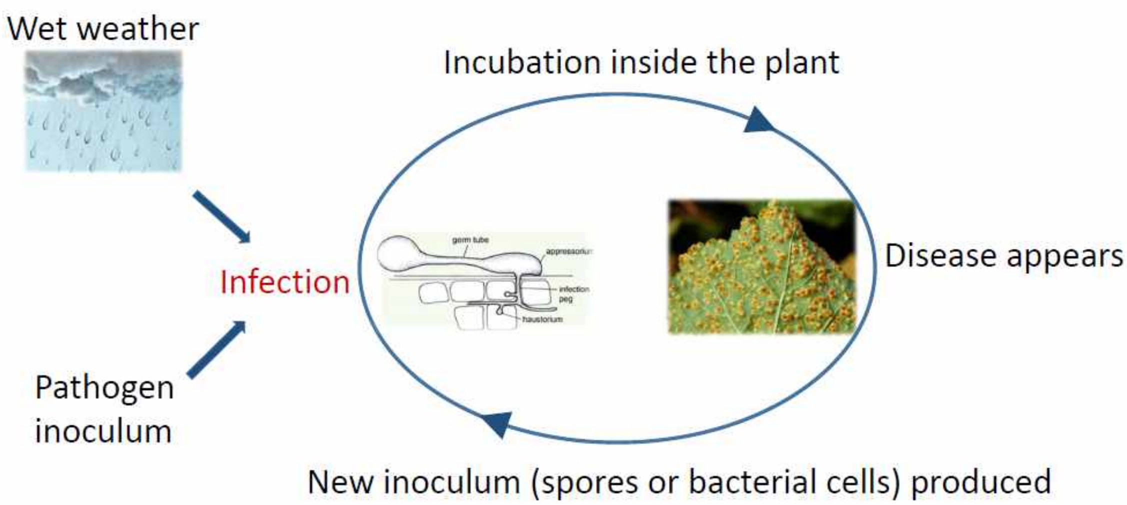
Each of these crops and diseases has required a risk model to be developed, either an original one developed in New Zealand, or one adapted from published information.

Knowledge required to implement disease warnings

To implement a disease warning system requires an understanding of:

- The biology of the pathogen that causes the disease, especially the response of infection to meteorological factors
- The disease cycle in the crop production system (interaction with crop growth and development)
- Local climate and seasonal weather dynamics
- Existing crop management practices used for disease control.

Plant pathogen infection cycle



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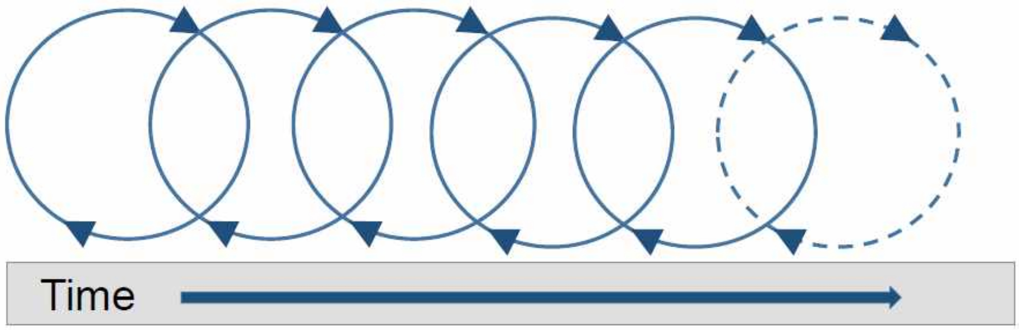
Polycyclic disease

Disease development is polycyclic, with a new overlapping infection cycle starting every time infection conditions occur.



Disease warnings using infection recognition

- If the meteorological conditions that allow infection are known, monitoring for these in the field can allow disease to be predicted
- This requires the risk model to accurately predict the relationship between weather and infection
- The delay before visible disease appears (incubation period) must be known.

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Infection and disease appearance for apple scab

Infection day 0

Disease appears ~ day 14

incubation period

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	days

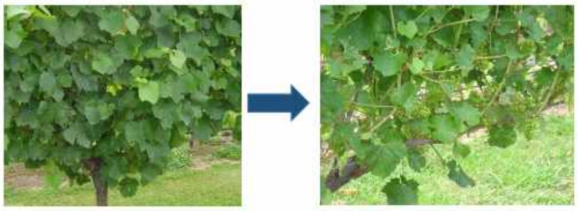
Disease warning development and implementation

Development and implementation of a disease warning system must be linked to knowledge of disease management practices in the target cropping system.

Understand existing control strategies

Fungicide or bactericide sprays are the usual method of disease control, although there may be alternatives, for example:

- Botrytis bunch rot in wine grapes, where non-fungicide management is as effective as using fungicides
  - Reduce canopy density to promote air movement
  - Remove bunch trash to reduce inoculum available for infection.



Disease management using infection recognition

- Crop spray regimes evolve over time to optimise a trade-of between the money return achieved by preventing disease versus all the costs associated with chemical use.
- Spraying frequency is dictated by the need to protect emerging plant tissue and to reapply chemicals after heavy rainfall.
- Standard regimes ensure that disease is controlled in the highest risk years
- This leads to unnecessary spraying in low disease risk years
- Weather-based disease warning systems aim to reduce spraying in low risk years by providing weather information to modify spray timing.

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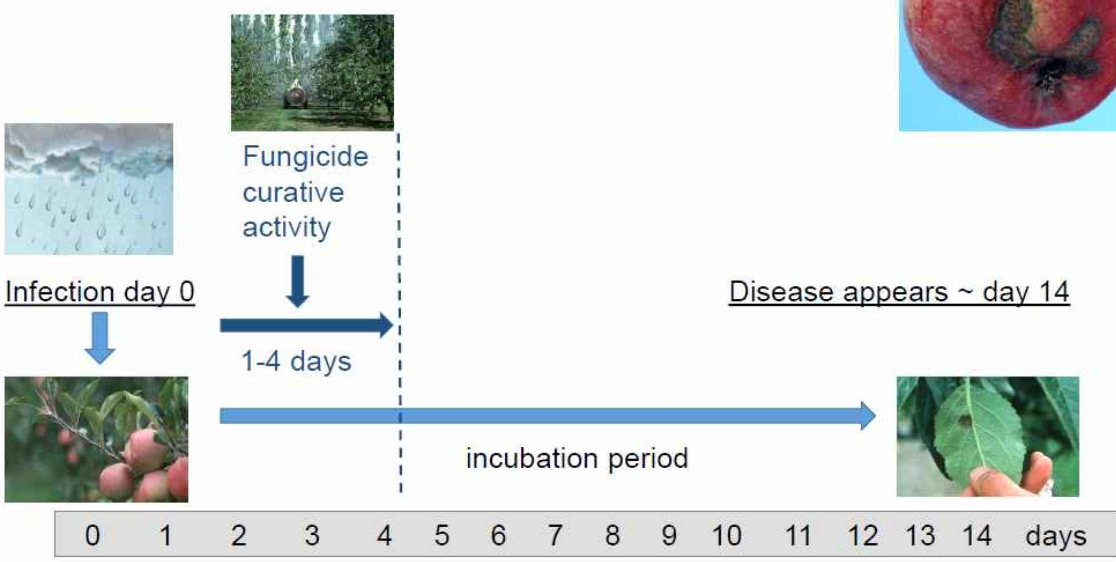
Disease management using infection recognition

- A quick response to infection can prevent disease appearing, if a curative fungicide is available, or if protective fungicide is applied before infection occurs (using weather forecasts).

Infection, disease and control for apple scab



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Meteorological variables for disease warnings

The most commonly used meteorological variables for disease warnings are:

- **Temperature** Easy to measure
- **Rainfall** Easy to measure, but high spatial variability causes local errors
- **Moisture (surface wetness)**
- **Moisture (relative humidity; RH)**

Vineyard weather station, Marlborough, New Zealand

Weather sensors for disease warning systems

Rainfall

- Tipping bucket rain gauge
- 0.1 mm sensitivity required because pathogens respond to wetting, rather than rainfall amount.

Texas Instruments tipping bucket rain gauge

Weather sensors for disease warning systems

Moisture, as surface wetness

- Wetness is the key variable that pathogens respond to
- However, wetness has high spatial variability, limited availability in weather data networks and not a standard World Meteorological Organisation variable
- Wetness can be modelled, either using empirical statistical relationships with RH, temp, wind, etc., or physical energy balance models.

CSI 237 wetness sensor

Weather sensors for disease warning systems

Moisture, as relative humidity (RH)

- RH sensors require frequent calibration and errors are common, especially in the 90 to 100% range suitable for infection by plant pathogens.

Stacked plate screen housing a sensor for temperature/humidity

Vaisala temperature/humidity sensor in a Stevenson screen

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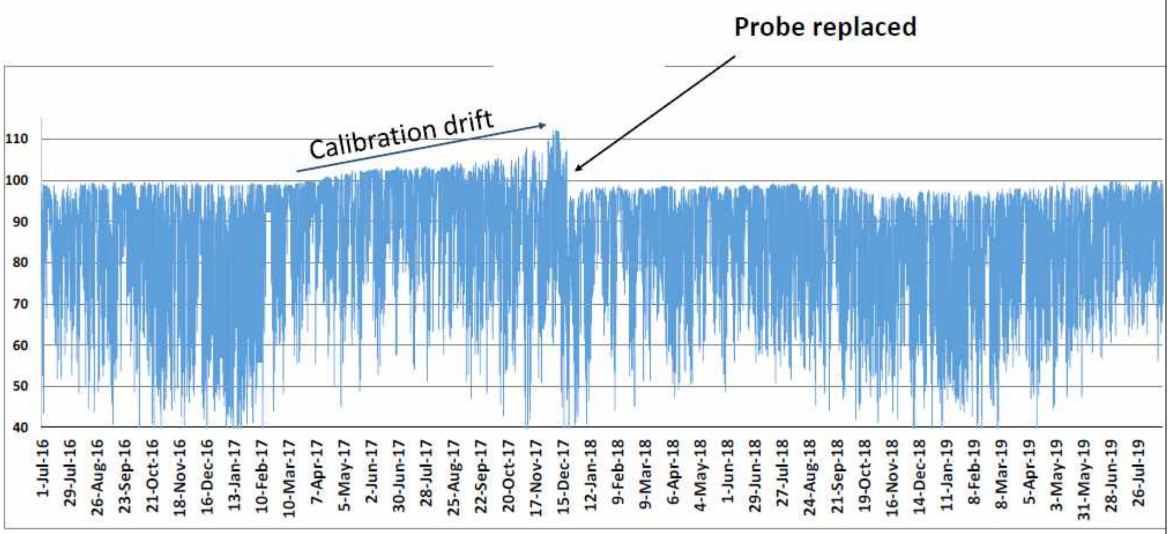
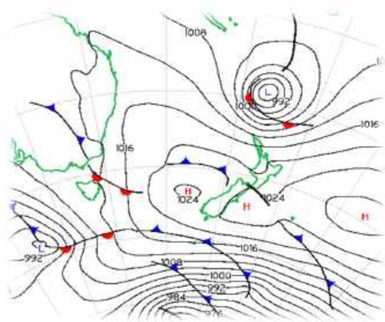
Calibration drift in a temp/RH probe



Broad-scale weather patterns diminish accuracy problems

Spatial variability and accuracy limitations in the measurement of moisture variables (wetness, RH and rainfall) are less important than expected.

- Rain-bearing weather systems that promote plant diseases occur as discrete events
- Passage of a weather system over a location changes conditions markedly
- networked weather stations at 2-5 km spacing on uniform topography are generally adequate to detect high risk periods



- However, there are marginal risk situations where spatial errors do matter.

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Sources of weather data for disease warnings

- Stand-alone weather stations with disease forecasting software (e.g. Adcon, Spectrum Watchdog ,etc). First developed in the late 1980s
- Weather stations networked in a region through telemetry and a centralised weather database
- Networked stations and a spatial interpolation algorithm to produce site specific estimates
- Virtual weather data grid of interpolated data or data generated from global circulation models and local area downscaling
- Weather forecasts for advance warning of incoming weather systems.

HortPlus™ horticultural weather station network

Each farmer or production site uses the nearest weather station and other stations may be used for back-up data if required.

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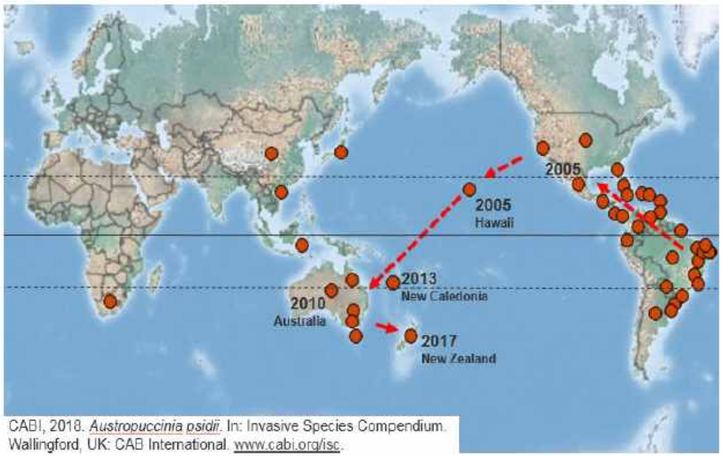
Numerical weather models for virtual data and forecasts

- Numerical weather models from global circulation models that are downscaled by local area statistical models for site-specific information
- For an early version of the kiwifruit Psa risk model, NIWA provided forecast maps using a NZ local area models to generate forecasts for 48 hours and 6 days ahead.
- For the Myrtle Rust Process Model, NIWA provides weekly risk maps using virtual data on a 1.5 km grid generated by the New Zealand Convective scale model (NZCSM)
- HortPlus risk warnings incorporate NZ MetService forecast data for 48 hours ahead.

Myrtle rust invasion of New Zealand

Myrtle rust arrived in NZ in 2017. A damaging pathogen; started spreading from America about 2005.



CABI, 2018. *Austropuccinia psidii*. In: Invasive Species Compendium. Wallingford, UK: CAB International. www.cabi.org/isc.

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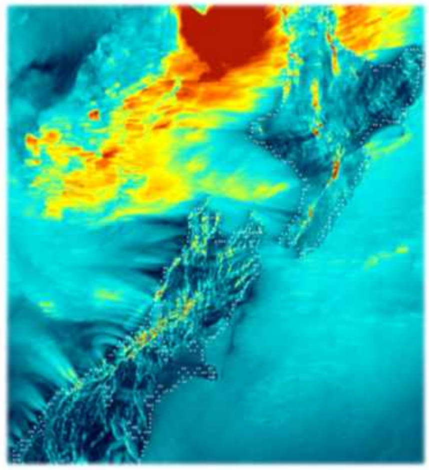
Myrtle rust risk model to help surveillance

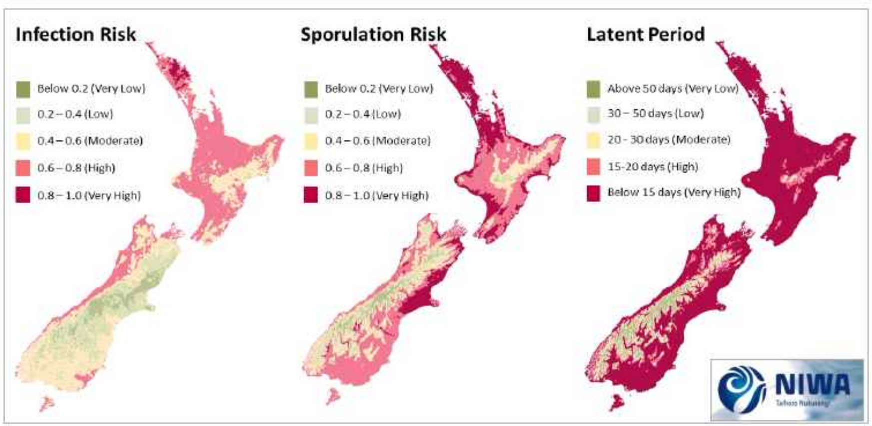
- An infection model was developed, which NIWA uses with the New Zealand Convective Scale Model (NZCSM) to produce a 1.5 km grid of risk based on hourly temp, RH and radiation.



NIWA

Myrtle rust weekly risk maps

- Infection risk is calculated daily and maps of weekly average infection risk are provided to agencies doing incursion surveillance and pathogen management.



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User uptake of disease warning systems

- Disease warning systems provide decision support for agricultural chemical use to control disease outbreaks
- However, disease warning systems often have low uptake by user groups, for a range of reasons
- The reason for low uptake is generally not because of problems with the quality or accessibility of meteorological data.

Reasons for failure of disease warning systems

- Risk model relies on a single threshold for a weather variable:
  - prevents discrimination of risk from no-risk situations when the weather variable values are in an uncertainty band either side of the threshold
  - makes the model sensitive to sensor errors and spatial variability
- Risk model or delivery system not suitable for user needs, or users are given inadequate training
- Underestimation of the cost of development, field validation and ongoing running costs of the system.

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Requirements for successful disease warning systems

1. Effective control chemicals or other disease management options
2. The relationship between disease and weather must be accurately represented in the weather risk model
3. Automated access to weather data, computer systems to process data and delivery of risk warnings
4. Risk events (warnings) must be infrequent relative to the frequency of control actions in a standard control regime. If events occur too frequently, there is no way for warnings to change spraying practices.

Requirements for a successful disease warning system

5. Farmers must have the flexibility with spraying operations to modify spray timing according to weather-based warnings.
6. There must be background drivers that favour reduced spraying, e.g. high chemical and spraying costs, government or industry regulated limits, or market access consequences from chemical residue risks.
7. Farmers must be involved in the design of the system and be properly trained on how to use it.

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Thank you

robert.beresford@plantandfood.co.nz

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