Factors affecting short and long distance dispersal of fungal pathogens – chickpea ascochyta blight as a model

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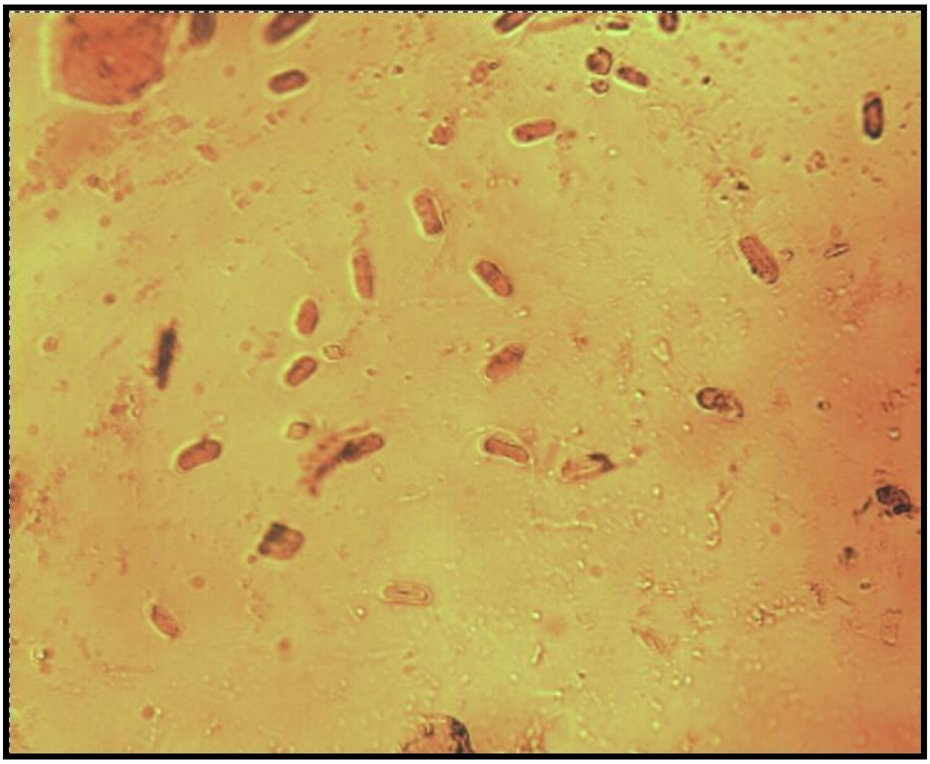

Wind and rain dispersed *Ascochyta rabiei* conidia trapped in the wind tunnel (photo by Steve Coventry)

All experience is a muddle, until we make a model to explain it. The model can clarify the muddles, but the model is never the muddle itself. "The map is not the territory"; the menu does not taste like the meal.
Dr Robert Anton Wilson

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Abstract

Exotic fungal plant pathogens pose a great threat to Australian agriculture. Some of the most devastating fungal pathogens are transported by rain splash, wind dispersal or a combination of both. *Ascochyta rabiei*, causal agent of ascochyta blight of chickpea, is a wind and rain borne pathogen already present in Australia. *A. rabiei*, therefore, provides a suitable pathogen for studying the potential spread of any exotic fungal pathogen having similar dispersion mechanism. In this study, firstly, laboratory and field experiments were conducted to examine the key environmental factors influencing the rain-splash triggered short distance and wind triggered long distance distribution of propagules (conidia) of *A. rabiei*. Secondly, a weather-based simulation model was developed and implemented for spatio-temporal dissemination of spread of chickpea ascochyta blight in natural environments.

The influence of temperature and relative humidity (RH) was studied on the viability of conidia of *A. rabiei* to help clarify in what environments the conidia initiate epidemics. Conidia were exposed to conditions of 5 - 45 °C (dry) and 12.5 - 100 % RH. Viability decreased from 100 % after 2 h at all the temperatures tested to 0 % after 144 h of exposure to temperatures exceeding 25 °C. Conidia failed to germinate when incubation period exceeded 8 h at 40 ºC. After 4 days of exposure to 30 - 35 °C germination of conidia was 1 - 88 %. Conidia remained viable and able to germinate when given optimum conditions following incubation in RH ranging from 12.5 to 100 % over a period of 96 h at 20 °C. More than 50% of conidia germinated following exposure to the lowest RH (12.5%) at 20 °C.

The effect of wind speed (m s^{-1}) and rain splash (mL m^{-1}) on the dispersal of conidia in a purpose-built wind and rain tunnel was investigated. Conidia were trapped on 40 cm tall x

2 mm wide rods placed between 2 and 110 cm along the tunnel; pieces of double-sided sticky tape were applied parallel to the rods at heights of 1 - 6, 11 - 16 and 31 - 36 cm. In the presence of simulated wind and wind-rain, conidia were distributed at least 66 cm, and the distance to which conidia were distributed increased with wind speed. Most conidia, in the order of hundreds to thousands, were trapped close to the inoculum source whereas fewer, in the order of tens to hundreds, were caught further from the source, with rain causing a greater number of conidia to be dispersed. Simulated rain also dispersed conidia to vertical tape positions 31 - 36 cm where none were trapped in the presence of wind alone.

Two field experiments were conducted to investigate the spread of ascochyta blight in natural environments at Kingsford (2007) and Turretfield (2008), South Australia. The disease was assessed following inoculation via infested stubble in plots (11 x 11 m each) for three chickpea cultivars, Howzat (moderately susceptible), Genesis 090 (resistant) and Almaz (moderately resistant). Logistic regression analysis was used to compare the rate of change of disease severity and the distance over which disease occurred. Weather data from a local automatic weather station were compiled and associations between wind direction, wind speed, rainfall, cultivar and disease severity were examined. Specifically, higher rainfall in 2008 was associated with faster rate and further spread of disease. In both years, disease spread was faster and further in Howzat than in Almaz, whereas no disease was observed in Genesis 090. Strong and continual winds in the southern and eastern directions in both years influenced the rate of increase in disease severity and the distance over which disease spread.

A spatiotemporal model was developed, based on Anthracnose Tracer for lupins, to determine the spread of ascochyta blight in natural environments. The model was based on a published model, written in Mathematica™ and runs on an hourly basis. The model is driven by the hourly weather data, *viz.* air temperature (°C), rainfall (mm h^{-1}), wind speed (m s^{-1}), wind direction (°), and standard deviation of the wind direction (°). The parameters of the model were estimated using the data collected in this study. The model was calibrated using 2007 field data. When validated with 2008 field data, the prediction from the model for the incidence of chickpea ascochyta blight closely matched with observation.

The results from this study have a number of implications. One, the newly developed model can form a basis for studying the likelihood of disease spread for exotic plant pathogens that have similar epidemiology to *A. rabiei*. Two, the model can be used to predict the pathogens, potential to cause damage in the regions where chickpea ascochyta blight has not yet spread. Three, this modelling work can contribute to the formulation of strategies for management of ascochyta blight in chickpea by targeted fungicide application and sowing regimes.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Steven Arthur Coventry and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text.

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Date:......................................

Statement of the Contributions to Jointly Authored Papers

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1. Development of a model to simulate the spread of ascochyta of chickpea in the field. Plant Pathology X:X-X [prepared manuscript]

Presented in chapter 7. Author contributions: SAC designed and conducted all research experiments, analysed the data, and drafted/constructed the manuscript. MUS supervised the model development, calibration and application. ESS, JAD and MUS contributed to the research ideas and design, and the writing of the manuscript.

The manuscript displayed in this thesis is in submission form according to the instructions to authors of the specific journal. This thesis has been prepared according to the University of Adelaide's specifications for 'combination conventional/publication format'.

The following authors agree that the statement of the contributions of jointly authored papers accurately describes their contribution to the research manuscript and give consent to their inclusion in this thesis.

Coventry, S.A. ………………………………………………………

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Conference proceedings and presentations

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List of abbreviations

ANOVA	analysis of variance
BOM	Bureau of Meteorology
cv., cvs	cultivar, cultivars
DAFWA	Department of Agriculture and Food Western Australia
E	East
E_k	kinetic energy
E_{max}	average maximum kinetic energy
E_p	potential energy
FAO	Food and Agriculture Organisation
g	gravitation acceleration constant
h	hour
ln	natural logarithm
MAT	mating type
MPA	megapascal
MR	moderately resistant
MS	moderately susceptible
N	North
PDA	potato dextrose agar
R	resistant
RH	relative humidity
RWA	reverse osmosis water agar
S	South
SA	South Australia
SARDI	South Australia Research and Development Institute
Tunnel	Wind and rain tunnel
W	West
WA	Western Australia