Doctorat ParisTech

T H È S E

pour obtenir le grade de docteur délivré par

L'Institut des Sciences et Industries du Vivant et de l'Environnement

(AgroParisTech)

Spécialité : Sciences agronomiques et écologiques

présentée et soutenue publiquement par

Frédéric BERNARD

The development of a foliar fungal pathogen does react to temperature, but to which temperature?

Directeur de thèse : **Michaël CHELLE**

Co-encadrants de la thèse : **Ivan SACHE et Frédéric SUFFERT**

Jury

M. Jérôme CASAS	Professeur, IRBI, Université de Tours	Rapporteur
M. Michael SHAW	Professor, University of Reading, UK	Rapporteur
M. Bertrand NEY	Professeur, AgroParisTech	Examinateur
M. Philippe GATE	Directeur scientifique, ARVALIS - Institut du Végétal	Examinateur
M. Michaël CHELLE	Directeur de recherche, INRA UMR 1091 EGC	Examinateur
M. Ivan SACHE	Chargé de recherche, INRA UR 1290 BIOGER	Examinateur
M. Frédéric SUFFERT	Ingénieur de recherche, INRA UR 1290 BIOGER	Examinateur

AgroParisTech
INRA, UMR 1091 Environnement et Grandes Cultures
F-78850 Thiverval-Grignon

How the spatial and temporal scales of temperature impact simulated foliar fungal disease: the case study of *Mycosphaerella graminicola* on wheat

Frédéric BERNARD[1,2], Camille CHAMBON[1], Alain FORTINEAU[1], Ivan SACHE[3], Frédéric SUFFERT[3], Michaël CHELLE[1]

[1] INRA, UMR1091 EGC, F-78850 Thiverval-Grignon, France

[2] ARVALIS – Institut du Végétal, F-91405 Orsay, France

[3] INRA, UR 1290 BIOGER-CPP, F-78850 Thiverval-Grignon, France

One promising approach for spanning this diverse range of scales lies in the application of biophysics, which accounts for heat, mass, and exchange between organisms and their physical environment (Helmuth *et al.*, 2005). The leaf temperature can be estimated by Soil-Vegetation-Atmosphere transfer (SVAT) models using data recorded by standard weather stations. Such models, as CUPID (Norman, 1979), dynamically simulate the leaf temperature for each leaf layer.

This study aims at assessing the impact of the types of temperature and the time resolution (time step) on simulation outputs. To this end, the first purpose was to analyze the relationship between the three types of temperature (corresponding to three climate scales: mesoclimate, microclimate and phylloclimate) measured experimentally in wheat fields. The phylloclimate corresponds to the physical environment actually perceived by each individual aerial organ of a plant population (Chelle, 2005). Then, the second purpose was to compare these relationships to that established with simulation to ensure that temperatures are simulated accurately enough for simulating epidemics. The final purpose was to assess the impact of the type of temperature and the time step on the simulated epidemics. As a case study, we used the fungus *Mycosphaerella graminicola*, the causal agent of septoria tritici blotch (STB) on wheat. Present wherever wheat is grown and developing throughout the wheat growing season, this pathogen is exposed to a wide range of temperatures.

MATERIALS AND METHODS

Field experiment

Experimental setup

Experiments were conducted in two non-irrigated winter wheat (*cv* Tremie) plots, characterized by a deep silt loam soil, at INRA Grignon, France (48° 50' 43" N, +1° 56' 45"). In order to generate two different canopy architectures, the two winter plots differed by the sowing density and the nitrogen supplies. In the first field (field 1), winter wheat was conducted as an extensive crop with low sowing density (180 grains.m^{-2}) and low nitrogen supplies (65 kg.ha^{-1}). The second wheat field (field 2) was conducted as an intensive crop with higher sowing density (250 grains.m^{-2}) and nitrogen supply (210 kg.ha^{-1}).

Field temperature measurements

During the whole growing season, from November 2011 to July 2012, the temperature was measured simultaneously at three levels: (i) the air temperature of a meteorological station located less than 1 km from the field experiment (mesoclimatic temperature), (ii) the in-canopy air temperature (microclimatic temperature), and (iii) the wheat green leaves temperature (phylloclimatic temperature - Chelle, 2005). The mesoclimatic temperature was measured at an hourly time step by a standardized weather station (model Enerco 516i, CIMEL Electronique, Paris, France). The standard mesoclimatic temperature was measured at 2 m height above a grass canopy. The microclimatic temperature was measured with thin T-type thermocouples (diameter 0.06 mm) in each of the two wheat plots at five heights: every 25 cm from 0 to 100 cm. Finally, leaf temperature was measured on nine plants for each plot. For each plant, the temperatures of three green leaves of the main tiller were measured simultaneously with thin T-type thermocouples (diameter 0.2 mm) positioned under and in contact with the abaxial surface of leaf. In parallel to the crop growth, leaf temperature thermocouples were removed from the lower senescing leaves to the upper emerging leaves. The contact of thermocouples with leaves was checked three times a week. Thermocouples used for microclimatic and phylloclimatic temperatures were connected to a datalogger (Campbell Scientific®, USA) for each plot, recording leaf temperature every 20 s. The thermocouples and data-loggers were calibrated before and after the experiment.

Simulation of leaf and canopy air temperatures

Simulation of microclimatic air temperature and leaf temperature were performed using the CUPID model (Norman, 1979) that has already been used for pest simulations (Toole *et al.*, 1984; Rickman & Klepper, 1991). CUPID is a Soil-Vegetation-Atmosphere Transfer (SVAT) model that simulates energy fluxes between soil, vegetation and atmosphere. It uses weather, canopy (*e.g.* leaf physiological, canopy architecture), soil (heat and water properties) and site (*e.g.* latitude, longitude) characteristics as inputs (Fig. IV.1).