An environmental physics driven model for leaf wetness duration on winter oilseed rape

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ABSTRACT

Infection of winter oilseed rape by stem canker and light leaf spot depends on temperature and wetness(Toscano-Underwood et al., 2001). Due to lack of data on leaf wetness duration and of a wetness estimation model for winter oilseed rape, rain duration has been used as an approximation to wetness duration (Papastamati et al., 2002). We used methods of environmental physics to develop a model estimating wetness duration on leaves of winter oilseed rape. The model is a differential equation based on the principles of a single-layer energy balance equation (Pedro and Gillespie, 1982). It estimates hourly wetness amounts due to rainfall and dew and this output is converted into numbers of wet and dry hours. We compare model predictions with data given by the wetness sensor. The model provides a good estimate of wetness periods in comparison to the wetness sensor data. It is a new approach to modelling leaf wetness duration and applied for first time to winter oilseed rape. However, it is a flexible model that could easily be applied to other crops.

Key words: Environmental physics-Winter oilseed rape-Mechanistic model-Dew-Rainfall

INTRODUCTION

Environmental factors play an important role in the development of crop disease epidemics. For example, leaf wetness and temperature can affect direct interactions between the host and the pathogen (e.g. infection and sporulation processes), while rain and wind affect the transmission of inoculum between and within plants (Gillespie, 1994; McCartney and Fitt, 1985). In temperate climates, leaf wetness plays a crucial role in establishing two of the most damaging diseases of winter oilseed rape (canola) (*Brassica napus*); light leaf spot (*Pyrenopeziza brassicae*) and stem canker (*Leptosphaeria maculans*) (Gilles et al., 2000; Toscano-Underwood et al., 2001). For both pathogens the initial phase of the infection occurs in the autumn during the rosette stage, although damaging disease levels do not occur until the following spring and summer. Therefore, to prevent disease establishment and hence the development of damaging disease epidemics it is necessary to take appropriate control measures in autumn (Figueroa et al., 1994; West et al., 1999). As infection for both pathogens depends on leaf wetness, knowledge of crop wetness periods is essential for the development of accurate disease risk forecasts. However, leaf wetness periods are almost never measured in winter oilseed rape crops during the rosette stage, when the plants are most vulnerable to infection. A method for estimating the duration of leaf wetness periods from more readily available measurements of weather variables, such as temperature and rainfall, would greatly help risk assessment of the development of both light leaf spot and stem canker.

MATERIALS AND METHODS

Leaf wetness can be caused by rain, condensation, fog, mist, irrigation and gutation. Its duration is determined by the length of time needed for the water on a leaf surface to evaporate, however, water can also be lost by shaking or by being absorbed by the plant itself, although the latter is not very significant. The model described here assumes the leaf to be a horizontal flat plate that is not transpiring (i.e. equivalent to a wetness sensor). In autumn and winter oilseed rape grows slowly, thus transpiration plays only a minimal role in the leaf's energy balance. We assume that leaf wetness is caused by rain and by condensation and that water loss is due to evaporation although, runoff is implicitly included by assuming a maximum water carrying capacity of the leaf (see below). The model uses measured rainfall to estimate leaf wetness, $W(t)$, due to rain and an energy balance approach to estimate wetness due to condensation and water loss due to evaporation. The model essentially estimates wetness duration by calculating the time taken to evaporate water accumulated on the leaf by rain or by condensation.

Wetness sensors were placed in winter oilseed rape crops at Rothamsted during the autumn and winter (rosette stage) of 1997/98 and 1998/99. The sensors were Surface Wetness Sensors (Delta-T Devices, Burwell, Cambridge, UK) and were mounted horizontally on retort stand clamps at 0.2 m (approximately the crop height). Relative humidity, *RH*, air temperature, T_a and rainfall, *R*, were also measured just above the crop. Measurements made by these sensors were recorded using a Campbell 21X (1997/8) or 23X (1998/9) data logger (Campbell Scientific, Shepshed, Leicestershire, UK). Hourly average wind speed, U_m, at 1.8m, net radiation, *Rn*, and dry bulb temperature were measured at the Environmental Change Network site (ECN) at Rothamsted. The crop sites were 0.6 and 1.6 km from the ECN site in 1997/98 and 1998/99, respectively.

RESULTS

The model was run using the measured average meteorological data as input and the differential equation solved using the Runge-Kutta integration. The solutions for $W(t)$ for each hour were converted into wet-hours ($W(t)>0$) and dry-hours ($W(t)=0$) to facilitate comparison with the test data sets from the wetness sensor. The numbers of wet hours estimated for each day were then calculated. The number of wet hours for each day measured by the wetness sensor was also calculated. Model estimates and sensor measurements of the number of wet hours for each day, for both seasons, are shown in figure 1. In both seasons the model described the trends in wetness duration reasonably well but the model gave a better prediction during the 1998/99 season. The percentage agreement between model and measurements was 79.1% and 81.4% for 1997/98 and 1998/99, respectively. This was calculated for each season as the ratio of the number of hours the model correctly predicted as wet or dry to the total number of hours (measurements) in the season; this ratio has been previously been used as an indication of model accuracy (Kim et al., 2002).

DISCUSSION

Leaf wetness is a complex variable, as many factors affect the distribution and duration of water on a surface (Huber and Gillespie, 1992). It is affected by meteorological (physical) factors, such as temperature, rainfall, relative humidity, wind speed and radiation, and by biological variables relating to characteristics of the leaf surface and canopy structure. There have been many attempts to model wetness duration for different crops but as far as we are aware, this is the first time wetness duration modelling has been applied to oilseed rape crops. The model presented here was relatively simple compared to multi-layer energy balance. However, the single layer energy balance approach adopted here is appropriate for rosette oilseed rape because of the horizontal growth habit of the crop at this growth stage. The resulting model appeared to be robust and, as the parameter values used were derived from published data, the model (apart from weather data) should be applicable to other sites.

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