Project title	Epidemiology and prediction of rose downy mildew
Project number:	HNS 173
Project leader:	Professor Xiangming Xu
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Previous report	
Key staff:	Professor Xiangming Xu Joyce Robinson
Location of project:	East Malling Research New Road East Malling, Kent ME19 6BJ
Project coordinator:	
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Key words:	Prediction, infection

The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results, especially if they are used as the basis for commercial product recommendations.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Professor Xiangming Xu
Project Leader
East Malling Research

31 March 2011

Report authorised by:

Dr Christopher Atkinson
Head of Science
East Malling Research

Signature ....

31 March 2011

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Grower Summary

Headline

- A decision support tool for use in the management of rose downy mildew and powdery mildew has been further refined.
- Commercial evaluation at one rose site in 2010 suggested that the tool could considerably reduced fungicide input while maintaining good control of powdery mildew.

Background and expected deliverables

Downy mildew (*Peronospora sparsa*) is a highly destructive disease on roses, causing severe and rapid defoliation. Severe disease outbreaks are known to occur under humid conditions. All rose cultivars are considered to be susceptible to downy mildew although they can greatly differ in their sensitivity. Infection is generally restricted to young plant growth. Infected plants, particularly those with severe leaf abscission, are usually discarded because of possible infection of stems and hence the risk of diseased growth the following year. This not only results in production losses but also produces additional waste.

Intensive fungicide usage can result in unjustified applications and potential environmental pollution, and does not always control the disease satisfactorily due to poor timing or choice of fungicides, and may accelerate the selection of fungal strains that are resistant to fungicides.

Recent research on several crops has demonstrated that more careful targeting of fungicides can reduce overall fungicide use and provide successful control, although operating such an approach may place extra demand on producers. East Malling Research (EMR) developed a prototype powdery mildew forecasting model (under HNS 165) which can be used to assist with the better targeting of fungicides. This current project will develop a forecasting model for downy mildew and combine the two models within a single decision support tool (computer software) that could lead to improvements in the management of both diseases.

The decision support tool will be able to be used by growers to develop cultural methods that avoid creating favourable microclimate conditions for mildews, to time fungicide applications, and to select appropriate fungicides and dose.

Examples of management changes informed through the use of the decision support tool may include:

- programming irrigation schemes to reduce the risk of disease development, particularly in the glasshouse, based on the joint effects of temperature and duration of leaf wetness on disease development.
- using protectant crop protection products in the initial epidemic phase (i.e. early season) with the timing of application determined by disease forecasts as well as weather forecasts.
- using crop protection products that have high efficacy as an anti-sporulant when disease has already established in the crop, with the timing of application determined by disease forecasts as well as current disease level and weather forecasts.

Summary of the project and main conclusions

- The models use weather data (e.g. rainfall, temperature, relative humidity) and information on crop protection products (i.e. fungicides) applied to the crop and combines these data to forecasts infection risk from powdery and downy mildew.
- Understanding the level of infection risk can assist with the management of diseases (e.g. via product choice and through adjustment of application frequency or volume).
- Compared to the conventional crop protection management programme at Whartons Nurseries, Norfolk, a model-informed management strategy resulted in a 25% reduction in fungicide input whilst maintaining satisfactory control of powdery mildew.
- The rose downy mildew model was further revised to reflect environmental conditions that significantly influence infection. This includes the length of surface leaf wetness required at a given temperature for infection to occur and the influence of dry periods on the viability of downy mildew spores.
- Weather conditions in 2010 were not conducive for rose downy mildew development, and this affected the evaluation of the downy mildew model. Experiments will be repeated in 2011.

- The decision support tool (which incorporates both the powdery mildew and downy mildew models) was modified in response to feedback received from Whartons Nurseries and will be further evaluated at several commercial sites in 2011.
- A workshop to train growers in the practical use of decision support tools for the management of diseases is planned in conjunction with a British Rose Group event.
- A comprehensive Users' Guide, which contains simple but thorough guidelines on how to use the decision support tool to assist with practical disease management, has been refined.
- The Users' Guide will be submitted along with the Final Report for this project and distributed to rose growers along with the decision support tool.

Financial benefits

The initial evaluation suggested that the number of fungicide applications could be reduced (by around 25%) without jeopardising powdery mildew control on roses. Although the direct savings in actual fungicide product will be relatively small, because fungicides tend to be applied regularly from bud break onwards in a typical rose production programme a greater financial saving will be made in the labour costs associated with product application.

Action points for growers

- Attend the planned British Rose Group workshop on the use of decision support tools for the management of rose diseases during 2011.
- Contact Xiangming Xu at East Malling Research to find out how to get involved in trialling the draft version of the decision support tool.

Science Section

Introduction

Downy mildew (*Peronospora sparsa*) can be very destructive but tends to be sporadic in its occurrence (Horst, 1983). Although not as common as powdery mildew, downy mildew is considered in the UK to rank in the 'top four' most important foliar diseases of cultivated roses along with rust, powdery mildew and black spot. Infection is generally restricted to young, apical plant growth although it can infect leaves, stems, peduncles and petals. The main effect of the disease is short-term disfigurement caused by foliar lesions and extensive premature leaf abscission or 'leaf drop'.

Under humid, cool conditions, conidia and conidiophores appear copiously on the lower surfaces of leaves but, under less favourable conditions, spore production is sparse and difficult to detect (Wheeler, 1981). Sporangia germinate within four hours in water and germination was favoured under cool conditions (<18°C) (Breese *et al.*, 1994). Field observations indicated that as little as four hour wetness may be sufficient for infection to take place (Baker, 1953). Using detached leaves, it was shown that infection could take place after only two hour leaf wetness at an optimum temperature and disease severity increased with increasing length of leaf wetness (Aegerter *et al.*, 2003). Latent period ranged from four to seven days, depending on temperature (Aegerter *et al.*, 2003). In the same study, an empirical model was developed to describe the effects of weather conditions on development of rose downy mildew.

The fungus is believed to overwinter as dormant mycelium in cuttings and plants. However, the role of oospores in overwintering and initiating infections is less certain. Mycelium of *P. sparsa* may survive the winter in the cortex of rose stems (Wheeler, 1981). Systemic infections appeared to be important in rose rootstocks in the downy mildew epidemics seen in California (Aegerter *et al.*, 2002). Recent studies indicated that systemic infection in UK bush roses was not important and that oospores may have played an important role in overwintering (Xu and Pettitt, 2004).

Current knowledge on the biology and epidemiology of the rose downy mildew fungus is very limited. As a result, current control of downy mildew in roses relies almost totally on routine fungicide applications (10-14 day intervals between applications) especially in crops grown outdoors. In UK container-grown crops this can mean 10-15 sprays applied over the period from leaf emergence in spring to the onset of dormancy in autumn. Recent work has shown that compounds for control of potato blight that are effective against *Peronospora* species infecting other host species can give good control of rose downy mildew (O'Neill *et al.*, 2002). However, resistance to these compounds is widely seen in the oomycetes and especially in other downy mildews (e.g. *P. parasitica*). Recently HDC has funded work on evaluating alternative products for controlling rose downy mildew (HNS 135). Correct timing of fungicidal products is important, which is partially determined by the risk of fungal infections. A main aim of this work is to develop a decision support tool which can be used to forecast this risk to assist with the development of optimal control strategies for downy mildew. The work builds upon a prototype decision support tool for the control of powdery mildew (HNS 165). This work will produce a decision support tool that can be used by rose growers to manage both diseases.

Materials and methods

Model development

The prototype model is primarily based on the results from two published results (Breese *et al.*, 1994; Aegerter *et al.*, 2003). Two aspects of the actual forecasting model were revised based on the unpublished results obtained at EMR: infection conditions (length of surface wetness required at a given temperature) and fungal mortality during dry periods interrupting an infection process.

Model evaluation

A powdery mildew model (developed under HNS 165) was evaluated at the Whartons Nurseries, Norfolk, in 2010. The evaluation aimed to assess the usability of such models in a commercial setting and the usefulness of model forecasts for practical disease management. The usability of the system was mainly assessed in terms of (1) user interface, (2) ease of operating the systems, (3) logic flow in operating the system (particularly in handling weather data), and (4) presentation of model predictions. Because of this, it was purposely decided that the whole system would be managed by the grower alone, including initialising data loggers, downloading weather data, running the model, and interpreting model predictions for applying fungicides. During this evaluation phase, John Adlam of Dove Associates provided support to the grower as necessary. A battery powered data logger was placed in a rose plantation to record temperature and humidity; data were regularly downloaded to run the model.

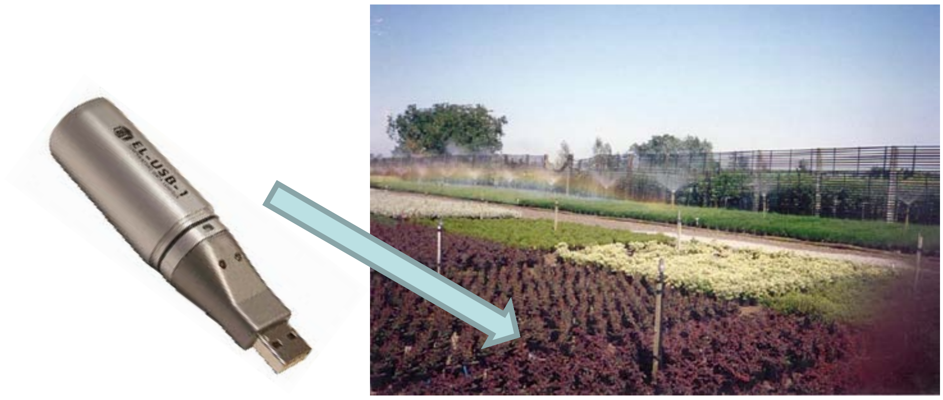

Figure 1. A simple diagram of the data logger and trial site for evaluating the mildew model

Epidemiology of rose downy mildew

Two isolates were obtained from a German researcher (Dr Dietmar Schulz, Inst. f. Pflanzengenetik, Abt. Molekulare Pflanzenzüchtung, Hannover) who is currently involved in rose downy mildew research for fungal isolates. These isolates were maintained on *in vitro* detached leaves.

Experiments were conducted to study the infectivity of *downy mildew P. sparsa* conidia on detached leaves *in vitro*. Four concentrations of conidial suspension were tested, and the experiment was repeated once. For each concentration, there were two replicate Petri dishes, each with up to 5 leaves (i.e. 15-25 leaflets). Detached rose leaves of an unspecified cultivar of the flower carpet type (known to be very susceptible to downy mildew based on the experiences of the grower) were first surface sterilised with sodium hypochlorite (0.025% available chlorine (w/v)) for 15 min, rinsed with distilled water immediately, and then inoculated with conidia (each leaflet receiving 10 µl of conidial suspension). Four levels of inoculation concentrations were used: 1000, 10000 and 100000, giving 10, 100 and 1000 conidia per leaflet, respectively. Inoculated leaflets were incubated at 10-12°C, regularly checked for infection by downy mildew. Sterile filter paper was put onto the surface of the agar to prevent the leaves disintegrating.

In order to monitor downy mildew development under field conditions, we placed several plants of two cultivars (Prima Ballerina and Zéphirine Drouhin) on a sandbed at EMR. These plants were regularly monitored for downy mildew.

Results

Model development

Two aspects of the actual forecasting model were revised based on the unpublished results obtained at EMR: infection conditions (length of surface wetness required at a given temperature) and fungal mortality during dry periods interrupting an infection process.

The prototype model has been revised considerably in several aspects, most of which was in response to those arising from the evaluation trial at the Whartons Nurseries. The following points were raised by the grower who evaluated the programme:

1) They are running the system on two different sites but that requires you to set up the last set of data and the master file every time you enter the programme. Can you make a .cfg file that remembers the master file, weather data file and fungicide file so you do not have to keep entering it?

2) Could you make the programme standalone? It would be good to be able to have two sets of the programme running so you can see how the containers and field are going at the same time. I have installed it twice in two different directories in an effort to try and have two different setups. I have set the targets in the shortcuts to the different sets of files but although they are in different directories if you change one it affects the other. Are there some common files used in the system32 or system directory?

3) We would like to be able to print out a graph. I can only do a screen dump of it.

4) I would like to be able to export the data or graph for analysis in Excel.

5) It would be good to be able to change the label on the graph, particularly where the programme has several different data sets.

6) The fungicide input needs to be separate as it uses the same fungicide data for any set of weather data. I was hoping that the two programme sets would overcome that but it seems whilst the fungicide data is specific to the programme set the master file uses only one set of fungicide data to any weather and master file. It would be good to have the weather data, master file and fungicide data all linked in some way;

perhaps through a “cfg” file so you can run several different sets on the one programme.

Points (1), (2) and (6) are about running the model for multi-loggers (multi-sites). Modifying the model to enable smooth operating multi-site (loggers) predictions has taken considerable effort but has been achieved. We have added an additional layer in defining the data structure when initially configuring the system for use at a particular site: defining the site name (and its associated logger data type and master data file name) (Fig. 2). Many sites can be defined; once a site has been defined, all the subsequent operations only need to refer to a particular site, including running models (Fig. 3) and entering fungicide spray information (Fig. 4).

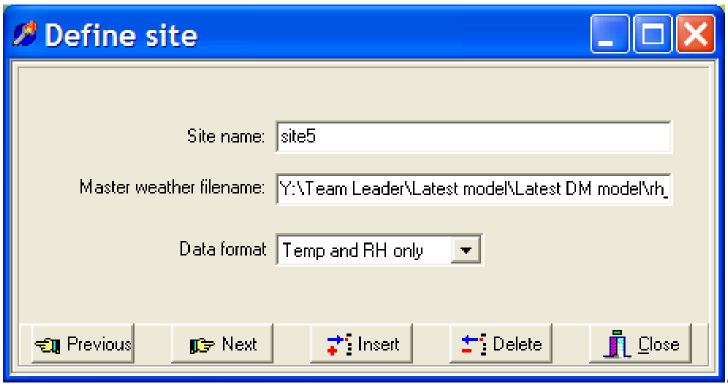

Figure 2. A screen shot of the form defining the site (data type and master data file name)

All other points have also been dealt with. For example the prediction graph now contains information about the site for which weather data were from and a ‘Print’ button to print predictions on the default printer (Fig. 5).

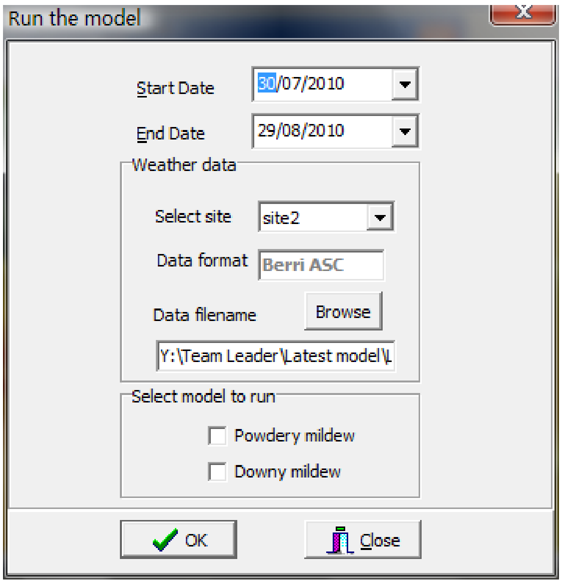

Figure 3. The ‘Run the model’ form

Additionally, we have added several tools for manipulating weather data, such as displaying daily weather summaries and calculating degree-days. We we have also included several pictures of rose diseases that may be of help to growers.

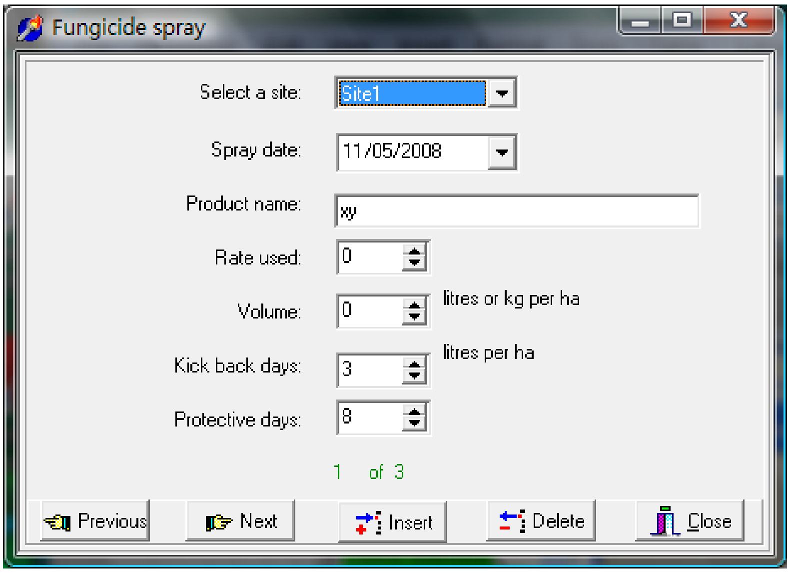

Figure 4. The 'Enter spray data' form

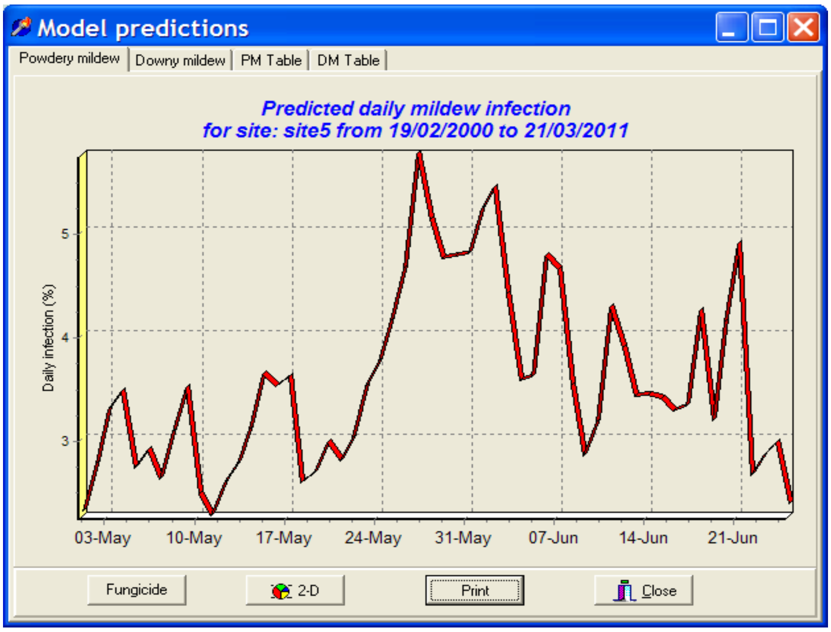

Figure 5. A screen shot of model predictions for illustration purpose only

Finally, we are developing a comprehensive Users' Guide, which contains simple but thorough guidelines on how to use the decision support tool to assist with practical disease management. The Users' Guide will be submitted along with the Final Report for this project and distributed to relevant levy payers along with the decision support tool in 2012.

Model evaluation

The model was trialled to assist in management of powdery mildew on an outdoor rose plantation during June and July in 2010. Compared to the conventional management programme, the model-based management strategy resulted in about 25% reduction in fungicide input whilst maintaining satisfactory control of powdery mildew. This preliminary result is very encouraging and the model will be evaluated on a four commercial sites in 2011. Commercial case studies will be incorporated into the Users' Guide to illustrate the precise nature of the decisions taken in response to the decision support tool.

Fungicides applied (conventional programme)

Date	Product	Cost/ha
14-04-10	Systhane	£21.86
14-05-10	Systhane	£21.86
25-05-10	Folicur	£25.23
07-06-10	Nimrod	£65.05
24-06-10	Amistar	£40.43
06-07-10	Folicur	£25.23
13-07-10	Nimrod	£65.05
23-07-10	Folicur	£25.23
09-08-10	Amistar	£40.43
Spraying	9 x £9.00/ha	£81.00
	TOTAL	**£411.37/ha**

Fungicides applied to trial crop

Date	Product	Cost/ha
14-04-10	Systhane	£21.86
14-05-10	Systhane	£21.86
24-06-10	Amistar	£40.43
06-07-10	Folicur	£25.23
13-07-10	Nimrod	£65.05
23-07-10	Folicur	£25.23
09-08-10	Amistar	£40.43
Spraying	7 x £9.00/ha	£63.00
	TOTAL	**£303.09/ha**

Experimental work

In both inoculation experiments, only a few leaflets developed downy mildew symptoms and thus we cannot draw any firm conclusion on conidial infectivity. In the coming season, we shall inoculate a few more cultivars for this experiment.

Downy mildew did not develop on the plants in the sandbed. Furthermore, downy mildew was not severe in 2010, most likely due to weather conditions not being conducive for disease development, which was also the general impression of the industry (we only obtained one sample of rose leaves with downy mildew symptoms from growers, which was kindly sent to us by Fryer's Roses).

Discussion

The initial model evaluation result are very encouraging: use of the model has resulted in about 25% reductions in fungicide inputs whilst maintaining satisfactory control of rose powdery mildew. The amount of fungicide saving is similar to that achieved in apple when disease prediction systems were used to manage apple scab and powdery mildew. Of course, the performance of any supervised disease management strategy depends on particular weather conditions during the evaluation period. Thus, we are planning to evaluate the system in several sites in 2011 with help kindly provided by John Adlam of Dove Associates. Furthermore, based on the evaluation in 2010, the system has been further revised to make it easier to operate.

The downy mildew model has been revised. Unfortunately, weather conditions were not conducive to downy mildew development in 2010. As a result, we did not obtain field data on downy mildew development to validate the model. In 2011, we shall try several approaches to obtain field data for validating the model:

1. Downy mildew development on outdoor rose plants at East Malling Research will be monitored and compared with the model forecasts.
2. Downy mildew development on selected commercial rose nurseries will be monitored and compared with the model forecasts.
3. Additionally, we are holding discussions with a research group in China (who are also working on management of rose diseases) to establish the potential for them to include monitoring powdery mildew and/or downy mildew epidemics in their disease programme

Conclusions

- The preliminary evaluation of the rose powdery mildew model is very encouraging, although limited to a single commercial site.
- The decision support tool's user interface has been revised based on this evaluation for easy use on multiple commercial sites

- The rose downy mildew model has also been revised but we failed to collect field data to validate this model because of unfavourable weather conditions in 2010

Technology transfer

- We have been in close contact with the grower and consultant in relation to the evaluation trial in 2010
- We have presented a talk on use of disease prediction systems on roses at a Rose Workshop organised by HTA in August 2009 and 2010.
- A training workshop on the practical use of the decision support tool is planned in 2011.

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