A DECISION SUPPORT SYSTEM TO ADVISE FARMERS ON APPROPRIATE FUNGICIDE APPLICATION TO PROTECT WINTER WHEAT FROM FOLIAR DISEASES

A. E. MILNE, E. AUDSLEY, D. J. PARSONS

Silsoe Research Institute, Bedfordshire, UK.
E-mail: alice.milne@bbsrc.ac.uk, eric.audsley@bbsrc.ac.uk, david.parsons@bbsrc.ac.uk

N. PAVELEY

ADAS High Mowthorpe, Duggleby, North Yorkshire, UK.
E-mail: Neil.Paveley@adas.co.uk

ABSTRACT

Dessac is an integrated suite of DSS modules covering the main decision areas confronted by arable farmers. The first of these modules advise to the user on fungicide application to winter wheat, based on optimising the crop margin. The science behind the module consists of a hierarchy of simulation models. The models consist of canopy growth, the development of four foliar fungal diseases, the effect of chemical sprays applied, yield from radiation light and gross margin optimisation. A sophisticated user interface, developed with extensive user testing, allows the user to play with number of applications, chemical, timing and dose, or request an optimum.

INTRODUCTION

Farmers typically spray a wheat crop three times during April to June to control fungal diseases. Different varieties have different susceptibilities and some of the highest yielding varieties are particularly at risk from the major diseases. The farmer has a choice of about 20 active ingredients which can be mixed in various combinations and applied at different dose and timings. Because of the complexity of the problem and the variability in disease attacks, there is a perception that farmers use too much chemicals as insurance. The DSS on wheat disease management seeks to improve chemical use by transferring expert knowledge and information captured in trials data to users.

The basic principle is that Foliar diseases reduce yield by destroying the leaves’ green area which would otherwise intercept light energy, and decrease the radiation use efficiency of the remaining green area (Bryson et al., 1995). Combining an understanding of crop growth, disease development, fungicide efficacy and yield accumulation is hence crucial when making decisions regarding fungicide application. The available knowledge consists of agronomic expertise, biological reasoning and experimental data sets. As such the simulation models used are semi-mechanistic and are driven by the seasons past weather data and a climatic prediction based on records of the site's past weather.

The concept of the DSS is a user interface in which the user investigates scenarios by altering model settings and observes the effect on disease, yield and margin as predicted by the model. The user can input observations of the progress of the crop or disease and set up hypothetical
situations in order to examine scenarios. The user is also able to request a list of the best spray plans for the scenario under consideration. The optimisation procedure uses a genetic algorithm to suggest a family of possible spray programs.

THE SIMULATION MODELS

The hierarchy of simulation models consist of canopy growth, development of four foliar fungal diseases, the effect of sprays applied, and light interception yield. Prediction of yield is notoriously difficult as there are numerous contributory factors. The combined aim of the simulation models is to make a prediction of the likely yield loss due to foliar diseases, thus avoiding the need for much of the complexity of other simulation models.

The system is site specific in that it differentiates between farms as a function of soil type, nitrogen available, sowing date of crop, the susceptibility of the variety to disease, weather data, etc. The model responds to these different data and predicts the future development of the crop, the disease and the yield under alternative future weather scenarios appropriate to that location. It must also make use of data typically available on a farm for example weather, growth stage observations and disease levels.

The canopy simulation is based on the ideas of several existing models. Developmental stages are assigned as a function of photo vernal thermal time (Weir et al., 1984) and leaves are set to emerge at a constant rate in thermal time (Kirby, 1994). What is novel is that the leaves are allocated emergence times in reverse from anthesis (Milne et al., 2001). This ensures that each leaf makes its appropriate contribution to yield and that recommendations are stable with temperature changes. The simulation was fitted to data from trials carried out over several sites and seasons which measured temperature and canopy development.

The major winter wheat foliar diseases, namely Septoria tritici, Yellow rust, Powdery mildew and Brown rust are modelled although the ideas can be extended to other polycyclic disease. The disease model simulates infection, disease progress and control on the upper six leaves of the canopy. Each day, a number of infection events occur on a leaf, each of which result in disease expression. Rate of disease development is for the most part controlled by temperature (King et al., 1983), and for this reason the growth of a unit infection is modelled as a function of thermal time. An individual disease expression is assumed to follow the solution of the logistic equation. The number of infection events that succeed each day is dependent on weather, nitrogen, cultivar resistance and fungicide activity. Total disease is the sum of the infections (Audsley et al. 2001). The models were fitted to data sets which came from experiments designed to investigate the effects of climate on disease growth.

Fungicides have two modes of action on foliar disease development. A protectant mode which kills infections that land on a leaf preventing them from growing, and an eradicant mode which slows down the rate of disease development. Most chemicals have both protectant and eradicant properties but some are solely protectants. Treating the epidemic as a single function does not allow the effects of fungicide timing to be incorporated into the model. This is why disease is built up from a series of infections (Paveley et al., 2001). The fungicide parameters were fitted to data from experiments carried out over several years which investigate fungicide activity at differing times and doses.

The yield loss due to foliar disease is calculated using a radiation interception yield model. Only healthy green area intercepts energy which forms yield. Diseased areas cannot intercept
energy and hence potential yield is lost. The model was fitted to data from trials carried out over several sites and seasons which measured disease area and yield.

Observations of canopy development and disease are used to modify predictions, where necessary. It is well known that observations of disease can be unreliable. Therefore expert knowledge and Bayes theorem are used to combine the prior probability of a site having high/low disease and the probability of an observed level of disease to modify the models level of disease.

OPTIMISATION PROCEDURE

A genetic algorithm procedure finds a list of the best solutions which optimise profit margin over spray cost. The allowable set of solutions consist of legal combinations of products at ¼, ½, ¾, and full recommended doses, at weekly time intervals. The maximum number of treatments that can be applied is prescribed by the user. Similarity restrictions are imposed in order to make the list as diverse as possible. Full technical details are given in Parsons (2000).

USER INTERFACE

The system has been designed to be used by farmers and experts in real time situations, and as such much effort has gone into producing a user interface that is both simple to use and informative. Figure 1 shows the systems main screen and explains many of the features. Field and Farm information are entered into DESSAC data bases with the most relevant details displayed on the screen (i.e. sowing date, variety and weather).

A variety settings can be changed, for example spray application cost and spray timing and dose. Disease observations can also be recorded.

FIGURE 1. The main user interface screen of the wheat disease manager
TRIAL RESULTS AND CONCLUSION

Validation trials were undertaken to investigate the performance of the system as a whole, i.e. to assess the fungicide application decision support system. Within this remit the system was used to decide on spray plans for plots of winter wheat at 7 sites over two seasons. Information given to the system included variety, sowing date, weather and crop observations. As well as the WDM assessment trial plots unsprayed plots were also grown at each site.

Various data were collected: climatic data, leaf emergence and senesce dates, and growth stage dates, percentage disease observed on each leaf layer and yield. The state of the crop was assessed weekly.

In the first year a number of problems were identified and corrected. In the second year performance was satisfactory but the optimising model was not as good as expected with the system tending to apply too little fungicide. This problem has since been addressed.

REFERENCES

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