Project title:	Epidemiology of apple canker
Project number:	TF 19 [Previously APRC SP 19]
Report:	Reports 1990-1993
Project leader:	Dr D Butt, HRI East Malling
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Quarterly Report to APRC

Period ending 31st December 1990

APRC Project SP19

Title: Epidemiology of canker

Contractor: Plant Pathology Section, Crop Protection Department, HRI (EM)

An experiment with potted apple plants inoculated in winter '89-'90 was ended and the data analysed. Equations based upon infection-period conditions (duration of 100% relative humidity; average temperature in this 'wet' period) were produced to predict canker incidence at the leaf scars on inoculated shoots. Effects of cultivar resistance and age of leaf scar (when inoculated) were also measured.

Two new experiments with 3 apple cultivars and a total of 256 potted plants were started in the autumn. Fresh leaf scars and pruning cuts were inoculated with Nectria spores and the plants were then given periods of surface wetness varying in duration and temperature. These infection conditions were obtained in a glasshouse at HRI Efford. These plants are now incubating in polytunnels at East Malling and recorded weekly; first cankers appeared in December.

Also in Autumn three experiments were started to study effects of environment, host and pathogen on the infection of several thousand apple fruits. Fruits were cleaned, laid on trays in shallow boxes, sprayed with water, inoculated with spores at one site on each apple, and then the boxes were sealed in polythene so that the fruits were given different lengths of surface wetness at several different constant temperatures. Other factors included for study were cultivar, maturity of fruit when picked, site of inoculation on the fruit and spore concentration. The fruits are now incubating at 10°C and are examined weekly: assessment includes the identification of the fungus causing each rot as it appears.

Our present understanding of this disease has been systematically represented in a relational diagram. This conceptual model includes all phases of disease expression including fruit rots, and the processes of spore production and dispersal, infection and colonization, these being 'driven' by variables which describe the weather and the tree. The current experiments should provide the much-needed data to quantify parameters in this model and so lead to a practical forecasting system based upon sound biology and epidemiology.

A paper relevant to this project titled: "Modelling apple diseases and implementing warning systems under the constraints of applied research", was presented by Van Santen and Butt at an international meeting in Germany. A summary of this paper is appended.

D.J. Butt
4th January, 1991

MODELLING APPLE DISEASES AND IMPLEMENTING WARNING SYSTEMS UNDER THE CONSTRAINTS OF APPLIED RESEARCH

G. van Santen and D.J. Butt
British Society for Horticultural Research, East Malling, Maidstone,
Kent ME19 6BJ, England

Under a project partially funded by UK fruit growers, deterministic models predicting several airborne fungal diseases of apple are being built at East Malling. They include a revised model of scab (*Venturia inequalis*), and new models of canker (*Nectria galligena*) and powdery mildew (*Podosphaera leucotricha*). The suite of models is to be operated as a disease warning system on fruit farms. The project has to be pragmatic, urgent and economical; full use is therefore made of published data, and new experiments are kept to a minimum. Unfortunately, the quantitative information in publications is often inadequate. Why do authors (referees!) omit details needed for further applications of their data?

The first stage of this project is to use ACSL (similar to CSMP) to construct and verify simulation models of the dynamics of the infection (and sometimes sporulation) phase of the disease cycle. No attempt is being made to model the complete disease- or life-cycle. Next, the equivalent of the executable file of the model is transported from the VAX computer to a PC-system linked to electronic environment sensors. The model is run after each scan of the sensors: with the present automatic weather station this time step is 30 min. The third stage involves implementing the models on commercial equipment designed for use on farms; this disease warning system will be based on either a stand-alone environment monitor or an office-based PC linked to the outdoor sensors.

The main physical factors driving the infection process in these models are temperature, rainfall, surface wetness duration and relative humidity. In the scab model, account is taken of the mortality of the infection units during temporary unfavourable interruptions of wet periods: the population of inoculum is moved through three successive sub-processes of infection, with assumed differential mortality losses at each stage. Light (time of day) is another input. Other important inputs to these models are the degree of host resistance and the level of primary inoculum.

Where feasible, the output of the models is in the form of disease intensity. In the case of scab this has meant converting the 'light', 'moderate' and 'severe' infection risk levels of the well-known Mills' table into an equivalent scale of disease. This conversion will be described, together with the manner of incorporating the effects of inoculum and host resistance. Comments on this aspect of modelling will be sought: for models intended for use by growers, what is the best form of output?

Discussion will be invited on the questions raised above, and on the problem of reconciling a modeller's biological and epidemiological knowledge with inadequate quantitative data! Are there guidelines on bridging this gap by using "guesstimates"? Finally, the question of acceptable/unacceptable error in prediction will be addressed: again, what guidelines are there for models which will be used on farms at the 'sharp end' of short-term decision making?

Quarterly Report to APRC

Period ending 31st March 1991

APRC Project SP19

Title: Epidemiology of canker

Contractor: Plant Pathology Section Crop Protection Department, HRI (EM)

The resignation of G. van Santen and the appointment during this period of Dr. Xu to the APRC-funded apple disease projects SP19 and SP23 are described in the report on project SP23.

The data from the 1989-90 experiment in which apple leaf scars were inoculated (see previous report) was further analysed; a draft report being written in conjunction with van Santen is nearly complete.

The two experiments started last autumn, in which leaf scars and pruning cuts on 256 potted apple plants were inoculated and exposed to a range of infection conditions (see previous report), have been recorded weekly throughout the period. Cankers have been appearing and all have been removed soon after being first seen in order to minimise damage to the trees, each of which has multiple inoculation sites.

The three experiments started last autumn, in which apple fruits were inoculated and given a range of infection conditions differing in host, pathogen and environmental factors (see previous report), have been examined weekly. Inspections have taken place in the store rooms containing the trays of apples at 10°C. The incidence of rots has been high. Apples have been labelled and removed from the store immediately each rot has appeared and tissue from the diseased area has been removed and 'plated' under aseptic conditions in the laboratory. This operation has enabled every rot to be diagnosed by identifying the fungus cultured from the tissue. Many rots yielded pure isolates of Nectria, whilst others yielded mixed isolates. This laborious method has provided good quality data which we continue to collect, even though the job fully occupies the time of Mrs. J.D. Robinson (SO).

In conjunction with van Santen, details of the materials and methods used in all the autumn 1990 experiments have been 'written up' in anticipation of the final reports.

D.J. Butt
26th April, 1991

Quarterly Report to APRC

Period ending 30th June 1991

APRC Project SP19

Title: Epidemiology of canker

Contractor: Plant Pathology Section Crop Protection Department, HRI (EM)

The Report on project SP23 mentions that Dr. Xu started at East Malling on May 20th.

Data from the 1989-90 apple shoot experiment in which wounded leaf scars were inoculated (see previous Report) have been analysed. The final incidence of infected scars 190 days after inoculation, was higher on Cox than on Bramley; infection conditions (wetness duration, temperature) immediately after inoculation and also wound age had significant effects on canker incidence. Optimum conditions for canker were 20°C and 127 hours wetness; predictive equations were derived based on wetness duration and temperature. Incubation period (time from inoculation to first symptom) also seemed to be affected by infection conditions.

Recording continued in the two potted-plant experiments inoculated last autumn in glasshouses at HRI-Efford, and since kept in East Malling. No new leaf-scar cankers were appearing by late June, but pruning-cut cankers were still incubating. On scars, infection was affected more by wetness duration than by temperature in the wet period: wetness lasting more than 2 days was especially favourable. Scars on Cox were more susceptible than on Bramley and Golden Delicious. It seemed that significant infection of pruning cuts can occur after only 6 hours of surface wetness.

Recording also continued in the three apple fruit inoculation experiments (see previous Report). The detailed recording takes much time. A start was made to identify the many fungi isolated from fruit rots not caused by the canker organism.

D.J. Butt
4th September 1991

Six-Monthly Report to APRC

Period ending 31st December 1991

APRC Project SP19

Title: Epidemiology of apple canker

Contractor: Plant Pathology Section, Crop Protection Department, HRI (EM)

In contrast to apple scab, for apple canker there are few publications containing quantitative biological and epidemiological data suitable for building a predictive model. This project has continued, therefore, to place emphasis on the collection of new data. The recording of experiments started in autumn 1990 (see previous two reports) was concluded and the analysis of the large body of data collected has started.

Preliminary results are available from the three experiments in which fruit of several varieties were inoculated with canker spores and then immediately given wet periods (1, 2, 5 or 13 days) at a range of temperatures. After drying, the fruit were stored and *Nectria* rotting recorded. In general, the experiments were very successful with very few control (uninoculated) fruits developing rots.

Differences between varieties are mainly evident in whether the stalk cavity or cheek of the apple was most susceptible to infection; Spartan tended to become more infected at the stalk end, whereas the cheek was more often infected on Cox and Golden Delicious. There was a marked increase in the incidence of rots as the concentration of applied spore inoculum increased. The response to increasing duration of wet period was particularly marked, with many more rots following a wet infection period of 5 days than 2 days; longer wet periods only marginally increased the incidence of rotted fruits. Rot incidence also increased with temperature, but this variable was less important than wetness duration.

Together with the data collected from the inoculation of potted trees (see previous reports) this new information will be used to develop a model to predict infection by *Nectria*.

D.J. Butt
6th February 1992

5. Project SP19 (Mr. D.J. Butt) Epidemiology of canker

Emphasis has continued to be with the collection of new and previously unavailable data. The recording of several large artificial inoculation experiments was concluded. Some observations of importance have emerged from preliminary examination of results from an experiment in which fruits that were inoculated, exposed to controlled wet infection periods, dried, stored and assessed for the proportion of fruits with rots. Spartan was more prone to rot at the stalk end than on the cheek of the fruit, whereas the opposite was true for Cox and Golden Delicious. There was a large increase in rots when the wet period increased from 2 to 5 days, however, the effect of variation in temperature was less marked. These and other data will be used to build a predictive model that will indicate the risk of *Nectria* fruit rot after harvest.

Dr. I.R. Crute

Head, Crop Protection Department

6th February 1992

Six-Monthly Report to APRC

Period ending 30th June 1992

APRC Project SP19

Title: Epidemiology of apple canker

Contractor: Plant Pathology Section, Crop Protection Department, HRI (EM)

A 3-day meeting with Dr. E. van de Weg (The Netherlands) was important in focusing on apple canker. Aspects of canker biology were reviewed, with emphasis on the processes of infection and colonisation of leaf scars, pruning wounds, fruits and other entry sites. After this meeting Mr. Butt and Dr. Xu drew a detailed conceptual model replacing an earlier diagram: this new diagram represents the structural and dynamic relationships of canker biology. Subsequently, a simpler, working flow diagram was drawn, based upon our actual knowledge of the disease system: this practical model has been written as a computer programme for use on PCs. The model will alert growers to the risk of infection in the vicinity of existing cankers in an orchard.

The structure of Nectem™ (the canker warning system) is therefore in place, but completion of the prototype model is delayed pending some further experiments. One area for investigation is spore production, release and dispersal. Accordingly, *Nectria* cankers with perithecia were collected from an orchard and studied in a controlled environment cabinet. Airborne flights of ascospores peak 2-3 hours after wetting a canker, and in contrast to apple scab the spore discharge mechanism is not sensitive to light/dark. Again unlike scab, ascospores (and conidia) are effectively dispersed in water when cankers are wetted. A system has been set up to further study these events and collect data for the model.

Fruits on potted apple trees of several cultivars are being inoculated with *Nectria* conidia on four dates during this season. The purpose is to examine the effect of fruit age on susceptibility to infection. Also, to measure the minimum length of wet period needed to support infection: in this experiment the minimum wet period is 4 hours, compared with 20 hours in the 1990-91 study.

Report to APRC
Period 1st July 1992 - 31st March 1993

APRC Project SP19 (Rpt)
Title: Epidemiology of apple canker
Contractor: Plant Pathology & Weed Science Department, HRI (EM)

Studies in controlled environment cabinets of spore release from cankers were completed. Ascospores were discharged from perithecia into the air within 1 h of the start of simulated rain. For rain lasting no longer than 30 min, most ascospores were discharged over a short time, with peak catches 1-4 h and 4-7 h after the start of rain in light and dark conditions, respectively. For rain lasting 12 h, the first peak catch was 1-5 h after the start of rain when in light, and some ascospores were caught throughout the rainy period: in darkness, ascospores were again caught throughout the rainy period but numbers sometimes increased in the light period that followed rain, with a second peak catch 4-7 h after the end of rain.

Conidia (and a few ascospores) were present in the water flowing from cankers within 15 min of the start of rain. Conidia were released in water throughout 12 h rain periods. Light had no effect on conidial release.

These findings on the time and pattern of spore release were incorporated in the new *Nectria* model which in response to rainfall lands spores on pruning cuts, leaf scars and fruits. Equations to predict canker development in relation to surface wetness duration, temperatures and age of entry site were derived from earlier experiments. Pruning cuts are more susceptible than leaf scars. Further controlled experiments with fruit and leaf scars were started, mainly to measure the effects on infection of wet periods shorter than those previously studied.

Nectem™, the canker warning system under construction, will give alerts to infection by *Nectria*. Twelve fungicides were screened for their potential value as curative treatments applied in response to such alerts. On the basis of *in vitro* results, carbendazim, fenpropimorph and prochloraz are being tested on potted trees for post-infection activity.