Project title:	PC-based warning system for apple scab, powdery mildew and Nectria diseases
Project number:	TF 23 [Previously APRC SP 23]
Report:	Reports 1990-1993
Project leader:	Dr D Butt, HRI East Malling
Key words:	apple, apple scab, powdery mildew, nectria, disease, monilinina, gloeosporium, computer model

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Quarterly Report to APRC

Period ending 31st December 1990

APRC Project SP23

Title: Supervised control of scab, powdery mildew, Monilinina and Gloeosporium of apple

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

The East Malling apple scab infection model version 1.0 (EM 1.0) was completed. This dynamic model uses temperature, rainfall, duration of surface wetness and relative humidity to calculate the infection efficiency (IE) of ascospores and conidia. The IE is the fraction of viable inoculum which has infected by the end of the wet period. The model uses revised Mills' curves. Inoculum mortality is included in the model, being dependent upon stage of infection and RH. The model recognises the role of light in ascospore discharge. In validation tests, Mills' system detected no ascospore infection periods in spring 1989, whereas EM 1.0 registered eight warnings and primary infection did in fact occur, leading to scab in a monitored, unsprayed orchard. Likewise, an outbreak of scab in spring 1990 was predicted by EM 1.0 but not by Mills' system. An error was found in published American equations describing the revised Mills' curves being used: an appropriate correction in version 1.1 has improved the detection of infections due to conidia.

Historical observations of a powdery mildew epidemic on eleven cultivars were assembled into a database. The system allows the disease intensity recorded on individual leaves on extension shoots to be related to conditions at times when the leaves were at specified stages of development. Preliminary analyses were completed for one cultivar; final colony numbers on each leaf were regressed on both weather and inoculum variates measured earlier in the life of each leaf. The intensity of powdery mildew (the source of inoculum) on neighbouring leaves when a specified leaf was at stage '+1' (where leaf '0' is the youngest unrolled leaf, leaf +1 is the adjacent rolled (i.e. younger) leaf, and leaf -1 is the adjacent older leaf) was the main determinant of the final number of colonies on the specified leaf. At the susceptible +1 stage, infection (leading to visible colonies) is favoured by warm, humid nights and warm, calm days. As the specified leaf passed through stages 0, -1 and -2, colony development was favoured by the same night conditions, days which were dull, windy and humid and a slow rate of shoot growth.

At international meetings in Hungary and Germany, papers were presented outlining the EM scab model version 1.0 and the powdery mildew analysis, respectively. Copies of these papers are appended.

D.J. Butt
4th January, 1991

The East Malling Apple Scab Model Version I

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A new dynamic model, driven by temperature, rainfall, relative humidity and surface wetness, calculates the infection efficiency (IE) of both ascospores and conidia of apple scab (*Venturia inaequalis*) following their dispersal by rain. The IE is the fraction of viable inoculum which has successfully penetrated the host and established parasitic relationships at the end of a period of surface wetness. The calculation is based upon revised Mills' curves. Inoculum mortality during dry interruptions is included in the model, rates of loss being dependent upon the stage of infection and RH. The model recognizes that light plays a role in ascospore discharge. The new model was tested in 1989 by comparing its output with monitored outbreaks of scab in an unsprayed apple orchard. Whereas the Mills' system failed to detect important infection periods in spring, these were detected by the new model. In summer, both models accounted for conidial infection periods. The new model is seen as an improvement on the Mills' system.

In the United Kingdom, commercial apple orchards are usually treated routinely and protectively with fungicides to control apple scab (*Venturia inaequalis*), although the start of the spray programme on some farms may be delayed until the first infection period has occurred. Treatments may sometimes be made in response to regional warnings of infection periods, but in general, growers do not follow a strategy of post-infection curative sprays. It is certain, however, that in response to concern over public health and the environment there must be an early shift towards supervised disease control, whereby fungicides are applied only in response to local assessments of disease risk.

Simulation models of apple scab have been built; some were compared by Seem (1985). He noted that none of the models he examined are used in disease management. Also, to the best of our knowledge, the simulation model produced by Seem *et al.* (1989) is not in practical use. A disadvantage of these simulators is that they model the complete epidemic, leading to the problem that errors of prediction over the growing season accumulate to unacceptable levels.

Warning systems used in the supervised control of apple scab in various countries are mostly based upon Mills' Table (Mills, 1944). This table gives the durations of surface wetness which support light, moderate and severe infection over a range of temperatures from 42-78 °F. The table applies to only one process in the life-cycle, namely infection. Each wet period is considered a separate event leading to a possible outbreak of disease.

The fungicides currently available for the control of apple scab act protectively to prevent the establishment of the pathogen during a wet period, or curatively to kill recently established infections. It is logical, therefore, that practical warning systems focus on the infection process, as does the Mills' system, although the accuracy of warnings could be improved by including in the model the processes of spore production, discharge and dispersal. In the Mills' system, neither inoculum nor host factors are included.

New facts about the biology of apple scab have become available since Mills collected his data. For example, it is now known that a shorter duration of wetness is needed to support infection by ascospores than that presented in the Mills' Table (MacHardy and Gadoury, 1989).

This paper describes the structure and performance of the first version of a new scab forecasting model which incorporates some of the latest information on pathogen biology. This project was undertaken to see if improvements could be made to the Mills' scab warning system by using an alternative model, which retained sufficient simplicity for its practical application.

Materials and Methods.

Description of the East Malling Scab Model Version I:

The new scab forecasting model was built using the Advanced Continuous Simulation Language (ACSL). Model testing was done on a micro VAX II computer.

The model calculates the infection efficiency (IE) of inoculum on a scale from 0 to 1. The IE measures the fraction of the viable inoculum which has successfully penetrated the host and established a parasitic relationship (Butt and Royle, 1980). The prediction of infection is based upon two curves describing temperature and surface wetness duration requirements for light infection by ascospores and conidia, respectively. The ascospore curve differs from the one published by Mills (Mills, 1944) and summarizes the findings of several more recent experiments (MacHardy and Gadoury, 1989). An IE of 0.1 is equivalent to the light infection curve. The process leading to infection is modelled as a continuous process using the subroutine BOXCAR (De Wit & Goudriaan 1978); this is in contrast to the triple-threshold static system developed by Mills. In the East Malling model four sub-stages are distinguished in the infection process: spores landed, spores germinated, spores with appressoria and spores penetrated. It is assumed that the development rates of the pathogen population passing through these successive sub-stages are normally distributed against wet time.

When periods of dryness interrupt the infection process the negative effects on the survival of developing spores are included in the model. The rates of mortality differ for each sub-stage, and also depend on the relative humidity during the dry interruption, the higher the humidity the lower the rate of mortality (Olivier *et al.*, 1983).

According to the East Malling model, rain is the only dispersal agent of ascospores and conidia. Only a small proportion of the total ascospore population is discharged at the onset of rainfall beginning at night, but significant discharges may occur at dawn if the leaf debris remains wet (Brook, 1969a; 1969b; MacHardy and Gadoury, 1986; 1989). The model calculates the ascospore IE for every period of surface wetness initiated by rain, irrespective of the start time. For wet periods beginning at night the model also calculates the ascospore IE from the time of dawn.

Dew and fog are discounted as sources of water for infection by already landed conidia, because wind-blown conidia do not survive for long after dispersal (Johnstone, 1931; Severin, 1989). The conidial IE is calculated from the start of rainfall irrespective of time.

Comparative test of the model:

In 1989 the East Malling scab model (version I) was compared with the Mills' system for detecting infection periods in an unsprayed modern orchard of mixed apple cultivars planted in hedgerows at East Malling. Weather data to drive both models were collected at the East Malling Agrometeorological Plot which is adjacent to the unsprayed orchard. Mills' Periods were calculated from the original Mills' Table using the mean temperature over the wet period: according to standard UK rules, a maximum dry period of 4 hours, irrespectively of humidity, was tolerated between two successive wet periods.

Twice weekly during the growing season fixed samples, initially of rosette leaves, then extension shoot leaves and finally fruits were inspected for the appearance of new scab lesions on the cultivars Cox's Orange Pippin, Golden Delicious, Suntan and Crispin. On Cox, bud break and green cluster were on 10 March and 15 April respectively. The times of outbreaks of new scab lesions in the orchard were interpreted in relation to previous infection warnings given by the two models.

Results

Ascospore infection periods:

Figure 1 shows the occasions in spring and early summer 1989 when the models gave warnings of infection due to ascospores. The warnings by the East Malling model, ranging from very small IE values to nearly 1.0, are shown as two types; the IE's are calculated either independently of the time rainfall began or are based upon potential discharges at dawn for wet periods starting at night. Where a pair of bars in Figure 1 are of equal length (4 occasions), the potential infection periods started in daylight. In the cases where the pair of bars are of unequal length (4 occasions), the difference in IE is attributable to the delay until daylight of the start of the calculation of IE from a wet period begun in the dark. It can be seen that for the infection warning on the 2 April, which began in the dark, there was insufficient daylight time to support infection calculated from dawn.

No Mills' Periods were registered during the time span of Figure 1. Conditions registered by the Mills' system during this time came closest to an infection warning on 16 April, coinciding with the highest ascospore infection warning given by the East Malling model.

During the time covered by Figure 1 there were outbreaks of new scab colonies in two periods. Clearly, the Mills' system failed to detect the infection periods which led to these outbreaks. In contrast, the East Malling model registered six warnings in April before the initial colonies were observed. Allowing for incubation, these colonies were predictable from the output of the East Malling model. Later warnings in early June were followed by further outbreaks.

Conidia infection periods:

Figure 2 shows conidial infection warnings given by both the East Malling and Mills' models. All calculations of IE start irrespective of day or night conditions. In this figure the time is shown from when the initial colonies appeared (see Fig. 1). Warnings of high values of IE given by the East Malling model in July, August and September are associated with the continuous increase in the number of colonies from late July. Likewise, this rapid increase in the epidemic in summer was predictable from numerous and coinciding Mills' Periods: these ranged from severe (4 occasions) through moderate (3) to light (2).

Both systems failed to give a warning of infection leading to a few colonies that appeared in mid July.

Discussion

The most important feature of the 1989 test was the poor performance of Mills' system for forecasting outbreaks of apple scab during spring and early summer. Disease levels were not high during this period: incidences on four cultivars ranged from 1% to 46% scabbed clusters of rosette leaves, and 3% to 13% scabbed extension shoots. These relatively low incidences on the long shoots were associated, however, with 5% to 14% scabbed fruits (depending on cultivar). This indicates the risk of crop damage when the disease is not effectively controlled in the spring, even when scab may appear to be at commercially acceptable low levels following the primary infections by ascospores: subsequent generations of infection can result in significant attack on the fruits. The good performance of the East Malling model in identifying ascospore infection periods in 1989 was therefore an important improvement over the Mills' system.

In the secondary phase of the epidemic in the summer of 1989 there was much closer agreement between predictions given by the Mills' system and the East Malling model. In this respect it would seem that the Mills' system was detecting conidial infection periods. The outbreak of new scab colonies in mid July during a brief period was not predicted by either system: the interval following the infection periods registered in July is too short to explain this outbreak. It seems likely, therefore, that these colonies developed from infections on 29 June when neither warning system calculated infection risk from two wet periods: for the Mills' system, the dry interval was too long and for the East Malling model the humidity in the dry interval was too low. In fact, only two colonies appeared and so the environmental conditions were marginal.

It was not possible to verify the East Malling model for the accuracy of postponing the start of ascospore infection periods until dawn in the case where wetting due to rain starts at night. Although Figure 1 compares the infection efficiencies for the model run in the delayed and undelayed modes, outbreaks of scab cannot be attributed to either calculations. This would only have been possible by exposing trap plants to intercept inoculum for wet periods beginning in the dark, one group being exposed from the start of the wet period and one group at dawn: any differences in infection efficiencies of inoculum resulting from these two potential infection periods would then be detected as differences in numbers of colonies on the two groups of trap plants.

Although this report is limited to one season, the results show that Mills' system is not reliable and that the East Malling model version I is an improvement. Both systems calculate the risk of infection in terms of the weather conditions. The true level of disease will, of course, also depend on host and pathogen factors and these will be included in the second version of the East Malling model.

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Figure 1. Ascospore infection warnings in 1989
East Malling model

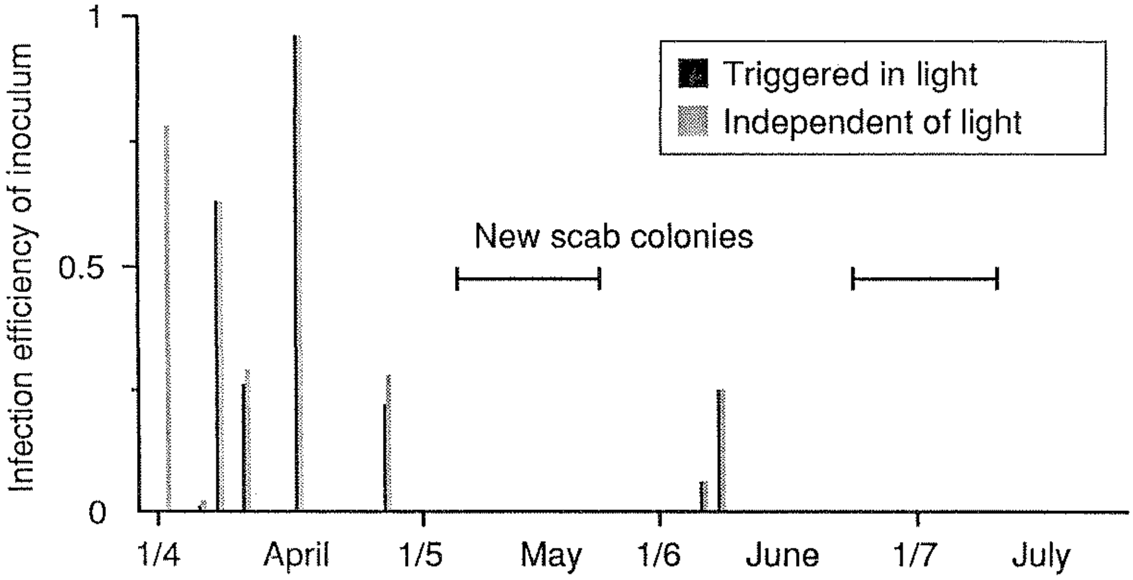

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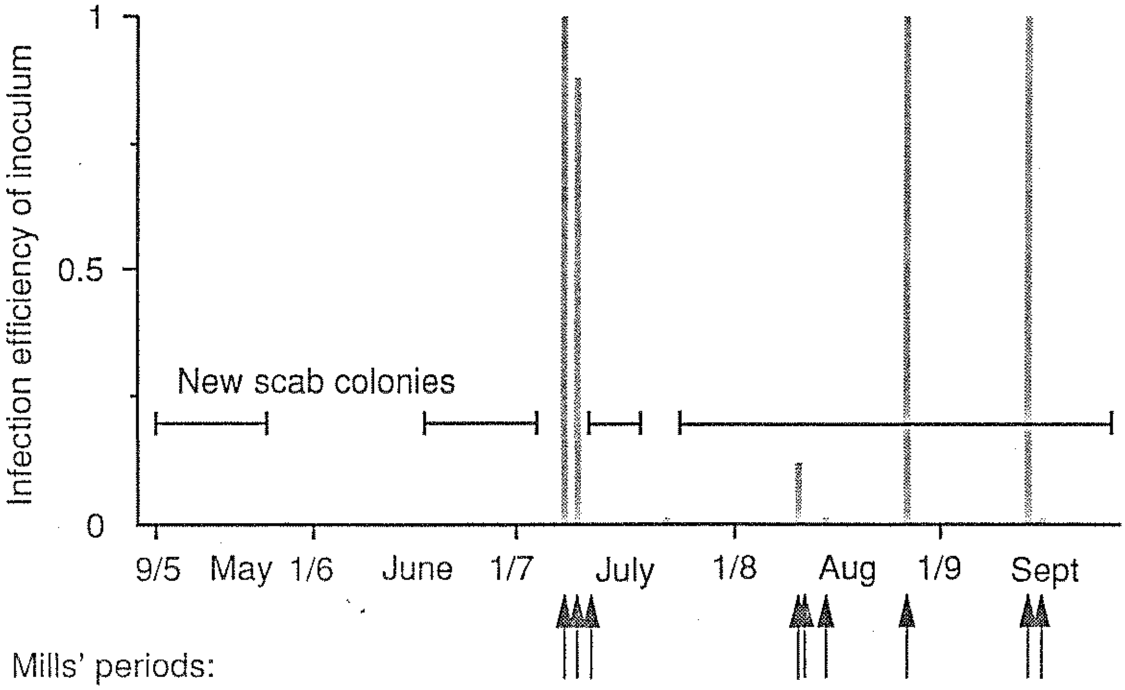
Figure 2. Conidia infection warnings in 1989
East Malling model



INTERPRETATION OF COLONY COUNTS AND INTENSITY OF POWDERY MILDEW ON SUCCESSIVE LEAVES ALONG APPLE SHOOTS

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Apple leaves are susceptible to infection by powdery mildew (*Podosphaera leucotricha*) only when very young; as they unroll and rapidly expand they become resistant. On extension shoots our convention is to number the youngest unrolled leaf '0'. Younger leaves are rolled, and are consecutively numbered +1, +2 etc., leaf +1 being at the node adjacent to leaf '0'. During times of rapid shoot growth the youngest visible leaf is typically at position +4; it is very small, cylindrical and tightly rolled inward on itself, exposing mainly its lower (abaxial) surface. Leaves at positions -1, -2, -3 etc. are older and increasingly larger than leaf '0'; leaf -1 is adjacent to leaf '0'. Leaves at positions +1, +2, +3 and +4 are especially susceptible to powdery mildew. Colonies develop until they first appear visible on about leaf -1. Sporulating colonies occur in the zone of leaves from +2 to -5 inclusive; colonies on older leaves tend to be stale.

An experiment was conducted to relate the final level of disease on individual leaves to weather conditions during specific periods (windows) of development of each leaf. The purpose was to provide data for a model in which the dynamics of shoot growth and mildew epidemics are coupled together in order to predict the intensity of disease on young leaves.

Potted plants of eleven apple cultivars were exposed to natural infection in a field relatively distant from apple orchards. Each cultivar consisted of a block of 30 plants (3 rows x 10 plants), the 11 blocks being arranged systematically along a line, from the most susceptible at one end to the most resistant cultivar at the other. Shoots were free of mildew when exposed. Secondary infections of mildew were recorded from early June to early September on 10 shoots/cultivar (in the middle row). Every fifth leaf was tagged to facilitate counting the total number of leaves at each inspection.

Shoots were inspected about three times each week: records for each shoot were the date, the total number of leaves (excluding the rolled leaves at the shoot tip), the number of visible colonies on leaves at positions -1, -2 and -3, and the estimated percentage area mildewed (from standard area charts) on the leaf at position -4. When a shoot had produced more than one new leaf since the last inspection the area mildewed was recorded also for leaf -5.

A summary of this data shows the time periods when each leaf was at the successive "development stages" +4, +3, +2, +1, '0', -1, -2, -3, -4, -5 etc. i.e. in terms of nodal position, the chronological history of every leaf is known. (This dating is derived from the total leaf count and the date when each leaf was at position '0'). A data base now contains the periods (dates) when every leaf was at successive nodal positions, a summary of weather factors pertaining to every period, and for every leaf the maximum colony count and the final percentage area mildewed.

The results of regression analyses will be presented and discussed.

Quarterly Report to APRC

Period ending 30th June 1991

APRC Project SP23

Title: Supervised control of scab, powdery mildew, Monilinia and Gloeosporium of apple

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

Dr. Xu funded by APRC, joined East Malling on 20th May to provide modelling skills in projects SP19 & 23 (see previous Report).

From 20th May to 30th June Dr. Xu examined the apple scab model (version 1) as developed by Gerard van Santen. Some features of the model were amended. For example, the minimal quantity of rain for spore release was increased, conditions for spore mortality were changed, infection was treated separately for ascospores discharged at night and in the day, and provision was made for spores to be released whilst spores of the previous release are still infecting. In these and other ways the leaf infection model was improved and became version 2.

By the end of the Quarter Dr. Xu had re-written the model in PASCAL. Version 1 had been in ACSL and could only be run on our main VAX computer. Conversion to PASCAL was a major step forward, allowing the model to be run on PCs; Version 2 was much 'friendlier' than Version 1.

The ADAS trial (under Dr. A. Berrie - see previous Report) started at East Malling in June: advice was given on trial design, treatments and environment monitoring. The 'software' team at East Malling prepared a friendlier VAX version of the scab model for use by Dr. Berrie to detect infection periods in the context of this 3-year study of HRI models.

Project SP23 was described to Terry Pryce (Chairman HRI) and the Chief Scientist's Group (CSG, MAFF) on separate occasions.

D.J. Butt
4th September 1991

Six-Monthly Report to APRC

Period ending 31st December 1991

APRC Project SP23

Title: Supervised control of scab, powdery mildew, *Monilinia* and *Gloeosporium* of apple

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

Emphasis has remained with apple scab. Minor modifications were made to the infection model. A new feature is a rule for detecting leaf wetness periods when the artificial wetness sensors on the weather station/data logger are dry! This anomaly between the tree canopy and the sensors can be especially serious in early spring and the new rule greatly enhances the value of the new scab warning system. The new infection model has performed better than a Mills'-based warning system in 1989 and 1991.

The infection model was extended with a second stage to take account of the fact that when weather conditions are favourable for infection, the amount of disease that will actually develop on a tree depends upon the amount of inoculum and the susceptibility of the variety. Both these latter factors are specific to individual orchards, and so predictions of scab risk given by the new, 2-stage model, are site specific and enable the grower to rationally decide upon curative treatment on an orchard-by-orchard basis.

Details of infection periods that occurred in any period chosen by the grower are displayed in a graph and in tables. The tables are designed to alert growers to the need to apply a fungicide and to decide in which orchards to accord priority.

Growers and advisers were consulted in the development of the new model as a computerised scab warning system, named VENTEM™. As a result, Ventem™ is practical and easy to use. Plans are well advanced for marketing Ventem™ internationally. Demonstration disks have been distributed, and a User's Manual is close to completion.

Ventem™ will run on IBM and compatible PCs and lap top computers. Ventem™ will accept weather data only from Metos® instruments: these instruments are manufactured by Gottfried Pessl, Austria. We will have greater control over the use of Ventem™ if we market it exclusively for use with this one make of weather station/data logger.

Mr. Butt and Dr. Xu visited Gottfried Pessl and demonstrated Ventem™ at the East Malling Members' Day and at the Marden Fruit Show.

4. Project SP23 (Mr. D.J. Butt) Supervised control of scab, powdery mildew, *Monilinia* and *Gloeosporium* of apple

Determination to build a model that is more accurate than Mills' table for predicting apple scab has culminated in Ventem™, a new, powerful and computerised scab warning system that runs on IBM and compatible PCs. The new system performed better than Mills'-based rules in 1989 and 1991 in orchard tests at East Malling. Growers and advisers were consulted in the final development of Ventem™ and, as a result, the system is practical and easy to use.

(23 Cont)

The final model used in Ventem™ has two parts. The first part (built before 1991) assesses the weather conditions (monitored by Metos® instruments) for their effect on infection; the second part (added in 1991) takes into account the fact that the severity of disease that may appear on a tree must depend also upon the amount of inoculum (number of spores) and the susceptibility of the variety. Both these latter factors are specific to individual orchards and so predictions by Ventem™ are site specific, and guide growers to decide upon treatments on an orchard-by-orchard basis.

Plans are well advanced for marketing Ventem™ with a discount to APRC subscribers in the UK.

Six-Monthly Report to APRC

Period ending 30th June 1992

APRC Project SP23

Title: Supervised control of scab, powdery mildew, *Monilinia* and *Gloeosporium* of apple

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

Ventem^{TM}, the new PC-based apple scab warning system, was commercially released in January, in both english and german languages. The system is being marketed internationally by Gottfried Pessl, manufacturer of the Metos^{R} weather stations used with Ventem^{TM}. Following much publicity of the new system, two workshops were held at East Malling, where about 25 people were instructed in the use of Ventem^{TM}. A user's manual was completed, and the package includes a tutorial for users who may not be familiar with PC operations.

Ventem^{TM}'s warnings of infection periods in the spring confirmed the orchard validation results in 1989 and 1991, that the new system is more accurate than a Mills'-based scab warning system. Clearly, the model used in Ventem^{TM} is satisfactory; however, scab literature was again reviewed in anticipation of updating version 3.1 later this year, when any perceived adjustments can be made. Minor problems with Ventem were rectified: failure to operate in the southern hemisphere (a "date" problem) will be rectified in version 4.

Two sets of powdery mildew data collected several years ago were intensively studied. In the first, infection was favoured by dull, cloudy, damp weather with high RH at night. Very susceptible cultivars (eg. Crispin, Golden Delicious) responded to weather differently from moderately susceptible cultivars (eg. Cox, Bramley): the model to be built for Podem^{TM}, the proposed powdery mildew warning system, will be based on the behaviour of the former group of cultivars. Predictions for more resistant cultivars will be by "adjustment downwards"; this approach to cultivar differences has been used in Ventem.

The second data set has provided information on day-to-day fluctuations in the concentration of airborne spores. The principle weather variable affecting concentration is rainfall.

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

APRC Project SP23 (Prot)
Title: Supervised control of scab and powdery mildew of apple
Contractor: Plant Pathology & Weed Science Department, HRI (EM)

Testing of the leaf scab infection model in Ventem™ continued in association with ADAS (Wye). The Ventem model detected four infection periods in April which were not signalled as Mills' Periods. Subsequent study of the monitored epidemic of leaf scab showed that these infection periods accounted for outbreaks of scab, confirming the superiority of the Ventem model over Mills' criteria in spring.

In addition to readings from surface wetness (SW) sensors, Ventem uses low vapour pressure deficit (VPD) - a measure of high humidity - to indicate wetness of apple tree canopies. This use of VPD had little effect on the scab alerts given by Ventem when using SW sensors alone over 3 years except on March 17, 1991, when a crucial infection period was only detected by using VPD. It seems likely that under certain weather conditions in spring, VPD is better than SW sensors for indicating wetness in the cup-like structures of opening fruit buds and rosette leaf clusters.

Data from South Africa was used to derive an equation to predict fruit scab from surface wetness, temperature and fruit age. Fruit scab warnings based on this equation are given by the new version (4.0) of Ventem™ which was developed. This update has other new features including improved cultivar susceptibility relationships, better presentation of information on infection periods, 'pull-down' menus, a spray diary and provision for use with several Metos® weather stations. Steps were taken to unify the appearance and operation of all APRC-sponsored models. Plans were made to incorporate into Ventem 4.0 the communication software linking Metos weather stations to PCs.

In preparation for PODEM™, the powdery mildew warning system, the analysis of historical data was mainly concerned with numbers of airborne conidia, because this is a major variable determining infection intensity. Several statistical techniques were applied to the number of conidia caught in spore traps in June and July over 5 years. Diurnal (i.e. day - night) periodicity of airborne spore concentration is correlated with diurnal patterns of several weather variables e.g. temperature, humidity. Also, spore concentration one day tends to be highly correlated with the concentration the following day. These correlations make it difficult to identify the causative effects of weather, but rainfall clearly has a major negative influence.

ALL +S +PROT

In preparation for experiments to quantify the dynamics of the infection process under a range of environments, techniques were developed to observe early stages of powdery mildew infection on young, inoculated apple leaves.

PC-based apple disease warning systems, including Ventem^{TM}, were described at meetings in France and Sweden and demonstrated at Fruit Focus and at an EMRA Members' Day.

Report to APRC

Period 1st April - 30th September 1993

APRC Project SP19/23

Title: PC-based warning systems for apple scab, powdery mildew and *Nectria* diseases

Contractor: Plant Pathology & Weed Science Department, HRI (EM)

Apple Scab

Collaboration with the HRI software engineers (Computing Department) continued in the updating of Ventem™ to version 4 for release in 1993; a start was made with writing a New User's Manual. Further steps were taken to simplify the operation of Ventem for users who may not be computer literate, and for users with multiple weather stations.

Powdery mildew

A major advance toward a disease warning system was made with the development of a model predicting the daily numbers of airborne conidia in summer. Over five years, the model output closely fitted the observed daily catches in spore traps. This is encouraging because of the importance of quantity of inoculum in determining the intensity of infection by powdery mildew fungi.

Techniques to observe the microscopic stages of leaf infection were further studied: these included stains, UV brighteners and the removal of the leaf epidermis. It is possible to detect the points where the germinating spores attempt to penetrate the epidermis, but it is not yet possible to recognise evidence of successful penetration and the establishment of a parasitic relationship. These studies are in preparation for controlled environment studies on the rates of infection at various temperatures.

Nectria diseases

An experiment to measure the effects of age of cut and length of wet period on the infection of pruning cuts by conidia, was conducted on potted trees of cvs. Cox and Fiesta. The resulting incidence of cankers was higher on Cox than Fiesta, and on both cultivars fresh pruning cuts were considerably more susceptible then those 24-h old. Over the range 2-12 h, increasing the length of the wet period led to only a minor increase in disease; clearly, pruning cuts are very susceptible and become infected in short wet periods.

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A fruit inoculation experiment in 1992 failed to produce many rots, possibly because of the delay of several weeks between harvesting and inoculating. Accordingly, another fruit experiment was conducted; Cox was harvested in August, 3 weeks before the forecast harvest date, and inoculated with conidia 3 d later. Inoculated apples were kept wet for 12, 24, 36 or 72 h at each of four temperatures in the range 10-25°C. These fruits are now in store at 5°C.

The test of three fungicides on inoculated pruning cuts and leaf scars failed to reveal any curative (post-infection) activity. It is possible that the interval of 3 d between infection and fungicide application gave too much advantage to the fungus, and so plans were made to repeat this experiment but with a shorter interval between infection and treatment.

Meetings

The following papers were presented at a major international workshop on orchard diseases held in Norway in June:

1. Ventem™ - a computerised apple scab warning system for use on farms.

2. The biology and epidemiology of *Nectria galligena* and an infection warning system.

3. Release of *Nectria galligena* spores from apple cankers.