REPORT ON A VISIT TO UNIVERSITIES AND RESEARCH STATIONS IN CANADA AND THE USA

TO DISCUSS DISEASE FORECASTING

23 April - 17 May 1990

By F M HUMPHERSON-JONES

OBJECT OF THE VISIT

The main reason for the visit was to discuss, with researchers in Canada and the USA, disease forecasters that had been developed there for scheduling fungicide sprays for the control of diseases of bulb onions. Meetings were also arranged with other scientists who had research interests in disease modelling and forecasting in other crops.

23/24 APRIL. PLANT PATHOLOGY DEPARTMENT, UNIVERSITY OF GUELPH, ONTARIO

Meetings were held with John Sutton, Terry James, Terry Gillespie, Gang Peng, Bob Hall, Greg Boland and Mark Sears.

John Sutton

'BOTCAST', an acronym for '*Botrytis* forecaster' and 'DOWNCAST', an acronym for 'downy mildew forecaster', have been developed at Guelph for predicting the optimum timing for fungicide application for the control of leaf blight (*Botrytis squamosa*) and downy mildew (*Peronospora destructor*) of bulb onions. In Ontario *c*. 2000 ha of bulb onions are grown annually and these diseases are a threat almost every year. Growers apply 6-12 fungicide sprays during the growing season.

BOTCAST

BOTCAST was developed mainly from empirical epidemiological studies on disease spread in onion crops in Ontario. Conidia produced on overwintered sclerotia in host residues, onion cull piles and soil are the main inoculum sources. The forecaster requires that r.h., temperature and wetness duration are measured hourly within the crop and from these data the model estimates the probability of weather conditions being favourable for sporulation and infection. For each day, from the time of crop emergence, a daily inoculum value (DINOV) and a daily infection value (DINFV) are calculated. These values are multiplied to produce a disease severity index (DSI) for each day and these values are accumulated to give a cumulative disease severity index (CDSI). The value of the CDSI is used to time the initial fungicide spray. Two spray thresholds are used: Threshold 1 when the CDSI = 21-30 and Threshold 2 when the CDSI = 31-40. The application of BOTCAST to epidemiological data for the years 1975-1981 showed that Threshold 1 and 2 corresponded to the occurrence of 1-5 and 6-15 lesions respectively on the lower three leaves. At Threshold 1, the risk of rapid disease increase is considered moderate and the initial fungicide spray is applied only when rain is forecast or before overhead irrigation is applied. At Threshold 2, the risk of rapid disease increase is considered high and the initial spray is applied as soon as possible.

Several assumptions are implicit in the model:

(A) Initial inoculum is always present.
(B) Wet periods required for sporulation are similar for sclerotia in crop residues or soil and for mycelium in dead leaves.
(C) Night temperatures are always favourable for sporulation.
(D) Conditions favourable for spore dispersal occur each day.
(E) Some spores produced at night survive until wet periods on the first or second night after sporulation.

The forecaster also includes a temperature-limiting component that returns a DINOV of 0 if temperatures on the previous day =>30°C for =>4 h, a condition that is unlikely to occur in the UK.

BOTCAST has been tested in Ontario over a period of 11 years. When Threshold 1 has been used to initiate a fungicide spray programme for control of leaf blight, 1-5 fewer sprays have been used than would be applied commercially. When Threshold 2 has been used, the number of sprays has been reduced by 2-6. In both cases disease control was equal to or better than that obtained with commercial spray programmes. BOTCAST has now been successfully used commercially in Ontario for three years by 'crop consultants' using Threshold 2 to initiate the first fungicide spray. Micro-climate is measured with chart recorders or, less frequently with electronic sensors.

One failing of BOTCAST is that once the first spray has been applied growers use a routine 7-10 day spray schedule until the end of the season even though weather conditions may be unfavourable for disease spread. John Sutton admits that further reduction in fungicide usage may be possible if subsequent sprays are timed according to weather conditions that are favourable for disease increase.

DOWNCAST

DOWNCAST requires hourly records of rainfall, r.h., temperature, rate of dew deposition and duration of dewfall measured within the crop. These variables are used to predict sporulation, spore survival and infection by the pathogen. DOWNCAST has been tested in experimental crops and it accurately predicted infection cycles of the fungus. The most effective timing for the initiation of fungicide spray programme was invariably when completion of the first infection cycle was predicted. DOWNCAST is not yet applied commercially, mainly because of the difficulties of accurately recording dewfall rate. Estimates of this variable are essential to the model since a dew period is needed for infection but spores are killed when dew is deposited only slowly.

Both BOTCAST and DOWNCAST assume the occurrence of initial inoculum at the time of planting. This assumption may be justified in Ontario, where onion cull piles are constantly present, despite efforts by Agricultural Advisors to ensure the effective disposal of this source. However, for both diseases, it is not known if this is the case in the UK and this factor must be taken into account when considering the implementation of these forecasters under our conditions.

Terry James

Terry James' research concentrates on the epidemiology of yellow spot of wheat. The main source of the disease is stubble and wheat trash from the previous crop. Perithecia are produced on stubble remaining above ground in the spring and ascospores are causal in initiating infection in newly emerged crops. The trend towards minimal tillage is considered to be a major factor in a recent increase in the incidence of this and other diseases of cereal crops. He is mainly interested in determining the conditions that favour perithecium and ascospore production with the aim of attempting to modify the micro-climate within the trash so as to accelerate ascospore production and release so that these events occur before emergence of the succeeding crop. A visit was made to Arkell Experimental Station where he carries out field experiments. The microclimate (temperature, humidity and rainfall) within infected wheat stubble is monitored throughout the autumn, winter and spring with electronic sensors and a Campbell data logger is used to store records. Temperature is measured at several heights within the trash (depth c. 4 cm) since it may vary considerably between soil level and the upper layers of trash. On the day of my visit (27°C and sunny) the temperature in the upper layers of trash was 38°C compared with 19°C at soil level. Evidently production of the sexual stage of the fungus is favoured by high temperatures and humidity and accordingly Terry James is examining the possibility of modifying the micro-climate in favour of ascospore production by sowing cover crops in the autumn.

Terry Gillespie

Terry Gillespie is an Agrometeorologist who has been instrumental in developing several electronic weather sensors including the wetness sensor that is considered essential for the application of BOTCAST. He provided me with such a sensor so that we can make our own for studies on B. squamosa. All of the electronic wetness sensors that he has developed are coated with a white (+ or - dye to simulate crop colour) latex paint. The paint is water absorbent and so disperses water droplets between oppositely-charged nickel wires so that the sensor is very sensitive to trace amounts of dew or rain. The type of paint is critical and it should contain the minimum of additives since these (wetters, emulsifiers) cause the sensor to respond to changes in humidity. The paint used is 'white latex' No. 88-6, made by the Pittsburgh Paint Co. I was unable to obtain a tin but Terry James suggested that any of the cheap white latex paints would be appropriate provided that, after painting the sensor, additives were removed as much as possible by repeatedly 'baking' the sensors. The sensors are heated in an oven to 100-104°C for 24 h directly after painting and then soaked in distilled water for 1 h. The process is repeated until the sensors do not respond to high humidity (tested in wetted polyethylene bags). For use in green crops, thallocyanine dye is mixed with the paint to produce the required colour. This addition also increases the sensitivity to trace amounts of water.

For detecting wetness on fruits and berries James strongly advocates the use of sensors made from spherical fishing floats (UK - Pike live-bait and fast-water trout floats) that have been filled or partially filled with water to a level that will give equivalent heat capacitance to that of the plant part being studied. As with other wetness sensors, oppositely charged nickel wires are wound into alternate grooves turned into the sensor surface and latex paint is used to increase sensitivity. He has evidence that correlation between wetness on such sensors and on the 'fruit' is high over a wide range of sizes. Water content of the sensors can be adjusted to ensure comparative drying times between the fruit and the sensor.

He has done many critical comparisons between wetness recorded by a wide range of electronic sensors and wetness observed on plant parts. Evidently the onset of plant wetness is accurately predicted by most sensors but large disparities in drying times are common. Accordingly he advocates that, in studies involving plant wetness, visual comparisons should be made between plants and sensors during the drying period following dew or rain, and appropriate adjustments made to the sensors to ensure comparability.

Gang Peng

Gang Peng is a post-graduate student of John Sutton. His research is on the biological control of grey mould (Botrytis cinerea) on strawberries. He has developed a leaf disc technique to screen potential antagonists and to screen host genotypes for resistance. Discs of strawberry leaves are inoculated with various micro-organisms and challenged with B. cinerea 24 h later. After a further 24 h the discs are placed on an agar medium containing paraquat and chloramphenicol and sporulation of the pathogen is assessed 5 days later.

Bob Hall

Cultivation of oilseed rape has increased considerably in southern Ontario in recent years and stem canker (Leptosphaeria maculans) has become a major problem. As in the UK, infected seed is the primary inoculum source and ascospores produced on the previous season's stubble are the main means of perpetuation. Minimum tillage policy is exacerbating the disease problem. Also, as in the UK, two distinct 'types' of the fungus occur in Canada, a highly virulent strain and a weakly virulent strain. In the UK bioassays have been used to distinguish the two types in seed stocks and in crops but the tests take 6-8 weeks. Bob Hall and his post-graduate student, Curtis Renfall are successfully using electrophoresis of culture medium or mycelium homogenate, with bands identified with glucose phosphate isomerase, to distinguish between virulent and non-virulent strains of the fungus. These tests are normally completed within 7 days and to date 100% correlation has been obtained between electrophoresis and bioassay tests. They have also tested several methods of detecting seed-borne infection by L. maculans. The most successful has involved incubating seeds in the dark on moist blotter for 48 h at 20°C, followed by 24 h at -20°C and 7 days at 20°C under near-U/V on a 12 h D/12 h L light regime.

Greg Boland

Greg Boland's main interest is white mould (Sclerotinia sclerotiorum) on oilseed rape and field beans with the emphasis on the development of a forecasting system based on the detection of ascospore inoculum and the early stages of infection on petals. In both crops ascospores from soil-borne sclerotia are the main infection agents. Conditions favourable for ascospore production coincide with the development of the crop canopy and flowering. Ascospores cannot easily directly infect leaves and stems but readily colonise petals. At petal fall the fungus invades leaf and stem tissue via infected petals to produce the damaging stem rot phase of the disease. Attempts have been made to relate ascocarp numbers with disease incidence but poor correlation precludes the use of ascocarp numbers as a basis for a predictor. He has used Morrell's method of plating on agar 200 randomly selected petals/crop and using the incidence of S. sclerotiorum colonies as an indicator of potential disease risk. Although the technique is reliable it is too labour intensive to be used commercially to predict the need for fungicide sprays. Moreover, since the test takes 5-6 days control measures may be applied too late.

He has found that surface-sterilising petals with propylene oxide significantly increases the recovery rate of S. sclerotiorum suggesting that natural antagonists may be present on the petals. He is studying the fungal populations on rape and bean petals with the long-term objective of producing a bio-control agent. At present he is not considering the role of bacterial flora. Epicoccus and Alternaria spp. are the dominant fungi present and he is attempting to develop antisera for these potential antagonists. He is also trying to develop monoclonal antibodies and DNA probes for identifying S. sclerotiorum on petals.

Mark Sears

Mark Sears works on the biocontrol of the Colorado potato beetle. At present this pest is controlled by furrow application of Temex which gives good control for up to 6-7 weeks but this insecticide will be withdrawn in most States this year and few good alternative insecticides are available due to major resistance problems. He has had demonstrated good control using Baccillus thiuriengensis applied as a foliar spray when 30% of larvae have hatched. The bacterium attacks the 1st stage larvae but not the eggs and accordingly a second application is needed 4-5 days later. Insecticide sprays are used later in the season. He has developed a simulator for predicting the development of the beetle based on daily temperatures and he is trying to link this with crop growth simulators for two potato cultivars.

25/26 APRIL. RIDGETOWN COLLEGE OF AGRICULTURAL TECHNOLOGY

The afternoon of 25 April and the day of 26 April was spent with Ron Pitblado who is on the Committee of the Ontario 2002 Integrated Pest Management (IPM) programme, a body charged with the responsibility of reducing pesticide usage in Ontario by 50% by the year 2002. The Committee are responsible for awarding State grants for research aimed at reducing pesticide use, for co-ordination of the development of IPM programmes and for educating farmers in the practical application of the programmes. Major components of many programmes are pest and disease forecasters. The application of weather-driven pest and disease management programmes is facilitated by the use of an increasing number of Agrometeorological stations within Ontario that record most weather variables (except leaf wetness) on an hourly basis. At present IPM programmes are mainly operated by scientific staff funded by the State but eventually it is intended that farmers will foot the bill. Threshold levels of pests and diseases for initiating control programmes are also major components of several IPM programmes and large numbers of students are employed in the summer to do the intensive scouting that is essential for their application.

A visit to a commercial mushroom factory was organised for the afternoon of 25 April and on 26 April discussions were held on aspects of disease and pest forecasting. His current research is on the practical implementation of weather-based forecasters for early blight, *Septoria* leaf spot and anthracnose of field tomatoes. He has developed a forecaster for these tomato diseases (TOMCAST) that was introduced to the growers in 1989. The model is driven by hourly, within-crop measurements of temperature and leaf wetness. As with BOTCAST and DOWNCAST the model assumes the presence of initial inoculum at the time of planting. The duration of leaf wetness and the mean temperature during the wet period are used to calculate a daily disease severity value (DSV) and daily values are accumulated. Fungicide application is recommended when a threshold cumulative DSV of 35 occurs. Subsequent sprays are applied when a further 20 units have accumulated. Owing to practical problems of within-crop measurement on farms he is investigating the potential use of standard meteorological data, collected twice daily from local weather stations, for estimating hourly records. The models being tested involve the estimation of leaf wetness duration from dew-point depression calculations and hourly temperatures from sinusoidal temperature curves fitted to max/min temperatures.

27 APRIL: VINELAND RESEARCH STATION, ONTARIO

John Northover

John Northover is a fruit mycologist with an on-going research programme on the epidemiology of black knot of cherry and on screening fungicides against a range of top fruit diseases. The work on black knot has only just commenced and the main aim at present is to study the effect of host physiology and weather conditions on disease development and in particular on ascospore production and release. His work on fungicide screening is prompted by build-up of benomyl resistance in several pathogens and by the imminent withdrawal of EBDC fungicides. These are a major component of disease control strategies for several top fruit diseases. As in other top fruit growing areas in Canada and in the northern States of the USA there is concern with the effect of the present mild winters on the incidence of powdery mildew. Hitherto, this disease has not been a serious problem in these areas since the fungus, which overwinters in the buds, is normally killed by hard frosts.

30 APRIL: OHIO STATE UNIVERSITY, WOOSTER

Meetings were held with Larry Madden and Mike Ellis.

Larry Madden

Larry Madden's main research is on splash dispersal of fungal spores and, in collaboration with other epidemiologists at Wooster and elsewhere, on the development and use of mathematical models to describe disease progress and to schedule fungicide applications. He is also interested in developing fundamental models for studying virus/vector relations and disease/microclimate interactions with major emphasis on virus and MLO diseases of maize and fungal diseases of fruit.

He uses tomato anthracnose as a model disease for studying splash dispersal of fungal spores and he has shown that, although the initial dispersal of spores away from a point source may be related to rain intensity, many other factors determine the final dispersal pattern and rain intensity alone is not correlated with dispersal distance. These include (1) the degree to which droplets containing spores are 'washed out' of the air, (2) the degree to which deposited spores are lost to the soil (3) the importance of redistribution and (4) the barrier to dispersal presented by the crop canopy. In row crops, the canopy effect results in most disease spread occurring along rows rather than between them. He has shown that soil texture is an important factor determining the significance of secondary dispersal and he is using glass beads of different diameters to simulate different soil surface characteristics. The beads allow inoculum loss to the soil matrix and also allow simulation of soils of different particle size. He uses a rain tower to subject artificially infected sporing tomato fruits to different rainfall regimes and uses physical means and bait plants to study spore dispersal. He has good data to show that total rainfall may be related to dispersal distance. By modifying the soil canopy he has shown that the use of a straw mulch restricts redistribution of spores and in tomato crops this practice gives excellent control of anthracnose.

Madden also has an interest in modelling the spread of virus diseases from single infected plants.

Mike Ellis

Mike Ellis is interested in the practical implementation of pest and disease forecasters in Ohio State with emphasis on diseases of top fruit. Evidently 24 forecaster models are available in North America and 12 of these are being used to some extent in Ohio. He works in close collaboration with faculty in the Environmental Biology Department in developing sensors and micro-processors for farm application. The main aim of this work is to produce simple sensors and cheap 'black boxes' into which can be placed interchangeable EPROM chips programmed with the appropriate disease models.

2 MAY: WISCONSIN STATE UNIVERSITY, MADISON.

Meetings were held with Doug Rouse and Paul Williams.

Doug Rouse

Doug Rouse's research is mainly concerned with the epidemiology and mathematical modelling of 'early-dying' syndrome and early blight of potatoes and bacterial brown spot of snap beans. He is very interested in combining crop growth models with models of pathogen development as a means of producing more refined forecasting systems.

Potato 'early dying' syndrome: The main cause of the 'early dying' in Wisconsin is Verticillium dahliae wilt. Doug Rouse has shown, by measuring photosynthesis and other biochemical processes in the leaves of infected plants, that the damage caused by the fungus can be attributed wholly to the physical blocking of the vascular system; no toxic effects or hormonal effects of the fungus on photosynthesis are associated with infection. He has developed models of fungal development which he is combining with a potato growth model with the purpose of predicting yield losses from infection incidence and/or soil populations of the fungus. The growth model has a number of sub-routines that separate various growth parameters such as carbon fixation, storage in leaves, storage in stems, storage in roots and respiratory losses. This model (SUCROSE) is driven mainly by temperature and radiation.

For local farmers he provides a soil testing service designed to indicate danger levels of V. dahliae. The test uses a selective medium to isolate viable propagules of the fungus and, if counts exceed 5 colonies/g of soil, a high risk of disease is predicted and soil sterilisation with Vapam is recommended. However, the accuracy of the prediction is confounded by the occurrence of the nematode Pratylenchus penetrans. When this is present at more than five nematodes/100g of soil there is a distinct interaction and disease incidence is increased. Accordingly soil samples are also tested for this nematode and the farmer is notified of its density. Since the interaction has not yet been quantified farmers must make their own risk assessments when both the fungus and the nematode are present. Evidently the synergism is not solely due to the fungus gaining easier access to the host through the feeding wounds of the nematode since closely related species that feed on the roots have no effect on disease incidence.

Early blight (Alternaria solani): As with 'early dying' he is attempting to combine the early blight model and potato growth model in order to predict yield reductions from estimates of disease incidence at various times. By doing this he hopes to be able to refine and improve the scheduling of fungicide application.

Bacterial brown spot: This disease caused by Pseudomonas syringae pv. syringae is controlled by routine prophylactic sprays of copper formulations, but the disease is absent in many years. The bacterium occurs naturally as a component of the leaf mycoflora (c. 10^4 cells/leaf before rainfall) and much of his recent work has focused on the population dynamics of the pathogen on snap bean leaves. He has shown that rainfall per se is not responsible for the spread of the disease. By using a selective medium and making colony counts to estimate the incidence of the bacteria on young snap bean leaves before, during and after rain (at 2 h intervals) he has shown that, during rainfall most of the bacteria are washed off the leaves so that the numbers are below the level of detection (10^2 cells/leaf) soon after the commencement of rainfall. After rainfall the population increases within 36 h to c. 10^6 cells/leaf and disease symptoms may subsequently develop. He has developed a forecasting system that involves sampling young leaves and placing them in a bath of de-ionised water at -2.5°C.

Since P. syringae is ice-nucleating the number of tubes that freeze correlates with the number of cells of P. syringae present.

The above forecasting system has worked well experimentally. In 1989, as a pilot project in collaboration with a major canning chain, he used the system to estimate the incidence of P. syringae in commercial crops of snap bean and to predict the need to apply copper sprays. The system was successful in predicting no requirement for sprays in any of the fields, at considerable savings to the growers.

Paul Williams

Paul Williams gave me a conducted tour of his fast-cycling Brassica rapa systems. A considerable effort is being devoted to producing seed and booklets for teaching purposes for a range of students from 6 years old to undergraduates. The teaching aids are selling well and are being used throughout North America.

4 MAY: MICHIGAN STATE UNIVERSITY, LANSING.

The day was spent with Mel Lacey who has been working on the development of a weather-related predictor for Botrytis squamosa leaf blight of onions for many years. A major objective of his work has been to produce a forecaster for scheduling fungicide sprays that could be operated by farmers with a minimum of sophisticated instrumentation. Other predictors for the disease require intensive scouting (see Loorbeer, N.Y. State), the use of precipitation forecasts (Loorbeer), whose reliability varies greatly with locality, and/or measurement of leaf wetness and temperature (Sutton, Guelph and Loorbeer). He has produced a forecaster based solely on the use of a hygrothermograph placed in the crop at 0.3m above ground. Predicting weather conditions favourable for sporulation is the basis of the forecaster and as with BOTCAST the model assumes the presence of spore inoculum at the time of sowing.

In developing the forecaster, a table with sporulation index values (SIVs) ranging from 0-100 was created empirically from spore trapping data collected over 2 years (Phytopath 73 670-676). Spore data were examined with multiple linear regression using 6 h periods of weather to relate to spore concentrations (MSTATC used on a P.C.). In practice, vapour pressure deficits are calculated by the farmer from r.h. and temperature, the table is entered with average temperature and average vapour pressure deficit values and the daily SIV is read off. The SIV represents 10 x ln of the number of conidia caught under similar conditions and a value of 50 is used to trigger a spray advisory. Because the conditions that favour sporulation are very similar to those that favour infection, prediction of spore release was considered to be sufficient for a predictive model without the addition of an infection component. In 4 years of experiments on growers farms, 2-6 fewer sprays were applied annually using the predictor than with conventional grower practice with no loss of disease control.

Mel Lacy provided me with the instructions given to farmers for use of the predictor. The programme can be run with a recording hygrothermograph, a hand calculator, a table for converting r.h. to VPD and a sporulation index table. It has also been placed on floppy disk as an interactive programme, called Onion Disease Management, available at a nominal cost from the Cooperative Extension Service, University of Wisconsin, Madison, WI 53706. It is also available in an automated weather station (Envirocaster previously Pestcaster) made by Neogen Food Tech.

8 MAY: NEW YORK STATE UNIVERSITY, ITHACA

A meeting was held with Jim Loorbeer and several of his students. Loorbeer has developed two forecasters for managing Botrytis leaf blight of onions. The first has been used successfully in New York State for several years and is based on applying the initial fungicide spray when leaf blight reaches a critical disease level (CDL) of 1.0 lesions/leaf. Thereafter, routine fungicide sprays are applied on a 4-10 day basis. Scouts (mainly university summer students) are employed and paid by the New York IPM programme to do the necessary frequent disease assessments.

The second forecaster (BLIGHT-ALERT) has been developed recently to time the application of subsequent sprays based on an inoculum production index (IPI) and an infection risk. The IPI forecasts the production of inoculum from measurements of temperature, r.h., and crop development, and National Weather Service forecasts of precipitation probability are used to predict the conditions favourable for infection. Much of the work on this forecaster was done by Paul Vincelli (now in Plant Pathology Dept, University of Kentucky, Lexington). BLIGHT-ALERT is not yet been used commercially.

B. squamosa sporulates poorly and inconsistently in culture. I was provided with extracts of a submitted thesis by one of Loorbeer's recent students (Balis) in which there are descriptions of critical work on the stimulation of sporulation in B. squamosa.

Loorbeer is also very interested in synergism in fungicide mixtures. He has tested fungicide mixtures against a range of diseases of onions and other crops and has demonstrated synergism with several mixtures. The highest synergistic effect has been obtained by including a low rate of a dicarboximide fungicide with a full or low rate of a dithiocarbamate fungicide.

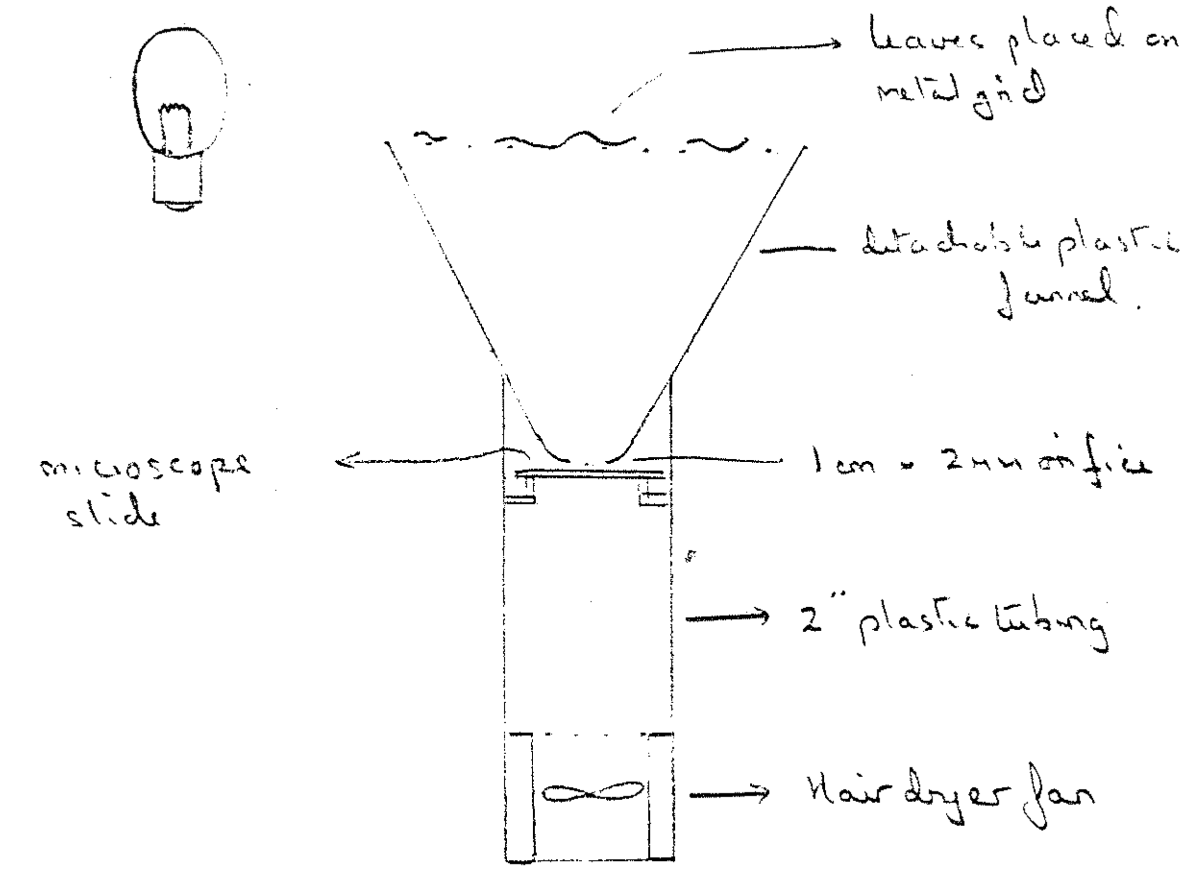
10 MAY: NEW HAMPSHIRE STATE UNIVERSITY, DURHAM.

The day was spent with Bill MacHardy and his students. His main research programme is on apple scab (Venturia inaequalis) with the emphasis on predicting optimum fungicide spray timing and on methods of reducing the overwintering source of the disease on dead leaves. He has designed a cheap spore trap for detecting ascospores that may be used both in the laboratory and in orchards (Diag 1.).

The traps are used to test the effect of chemical treatments on ascospore production. In the laboratory they are used with the funnel uppermost and in the orchard they are reversed over 1 m^2 areas of infected leaves. For laboratory studies leaves or leaf discs are wetted and placed on the grids adjacent to a light source (60-100 w) and spores are sucked over an untreated microscope slide by means of a hair-dryer motor. The cheapness of construction means that several traps can be used and so good statistical replication is possible. In collaboration with Alan Gotlieb (Dept of Plant and Soil Science, Vermont) an ELISA test has been developed which identifies individual spores on spore trap slides as a distinct red spot. A patent for the technique has been submitted. They are also attempting to produce a monoclonal anti-body to the ascospores (Abstract in Phytopath).

Diagram 1

Cost ≤ £6 per trap



MacHardy is adopting an approach of minimising over-wintering inoculum as a means of disease control. One method he is using is to chop the fallen leaves in the autumn by mechanical flailing with the objective of minimising the probability that two infections of opposite mating type may occur on the same leaf fragment and so be in a position to produce the sexual stage. However, although old leaves are considered to be resistant to infection, soon after harvest, leaf infection increases dramatically so that the potential incidence of the sexual stage may be high. In order to overcome this problem he is examining the use of defoliants to accelerate leaf fall and so minimise build-up of inoculum. He is also applying urea sprays pre- leaf fall and in the spring to encourage microbial degradation and to suppress perithecium formation. Results to date from such treatments applied in autumn, 1989 and in spring, 1990 are very encouraging and indicate that ascospore production has been delayed by at least 3 wk.

He is attempting to use a measure of potential ascospore dose (PAD) derived from disease incidence in the autumn to predict disease risk in the following season. 1000-leaf samples are assessed in the autumn for the incidence of leaf infection and the number of infections/leaf. Knowing the approximate number of leaves/m^2 of orchard, the number of perithecia produced/infection and the number of ascospores produced/perithecium, he estimates the potential number of spores/m^2 of orchard in the spring. However at present he does not know how the PAD correlates with disease risk. In 1990 he plans to 'clean up' several orchards, minimising the overwintering inoculum by use of a combination of flailing and multiple urea treatments, so that he can introduce inoculum of known PAD values to determine the relationships between PAD and disease risk.

He is testing the value of accumulated day degrees in the spring (from a range of base temperatures) in predicting ascospore maturity. For these studies the patterns of ascospore production are determined using both squashes of lesions and the spore traps described above. Evidently under New Hampshire conditions the period from 20% to 85% of spores maturing is about 10 days but variances are large. At present he is considering only weather conditions in the spring; he does not know the effect of autumn and winter weather on the time of spore maturation.

11 MAY-15 MAY: LEAVE

17 MAY: UNIVERSITY OF FLORIDA, GAINESVILLE

The day was spent with Rod Berger a plant disease epidemiologist who is interested in developing techniques for numerical analysis of epidemics, particularly with regard to control measures. Much of his recent work has been aimed at improving sampling techniques and optimising sampling times so as to minimise inaccuracies in interpretation of epidemic progress, and in comparing the effect of control measures on epidemic rate. He is concerned with the appropriateness of commonly used mathematical functions for describing disease progress and has done much research on comparing these functions for a range of diseases.

He has developed a forecaster for early blight (Cercospora apii) of celery that is widely used by growers in Florida. Between 25-40 fungicide sprays /season were routinely applied to the crop per season. The original forecaster was based on spray application following conditions favourable for sporulation (>8h high r.h. at >15°C) and was easily operated by the growers. Its commercial use led to considerable reductions in the number of applications, particularly in the winter months when low temperatures restricted sporulation. However, in some seasons, sprays applied according to predicted sporulation periods failed to give adequate control. These failures occurred where crops were grown sequentially in adjacent blocks. In these situations disturbance of one block by harvesting, cultivation, etc., caused widespread distribution of spores to nearby blocks and disease increase occurred despite the absence of a predicted sporulation period. Accordingly, a second system was developed based on fungicide spray application when air spore concentrations exceeded a threshold level. Spore concentrations are estimated using a volumetric spore trap sited within celery crops. For several fortuitous reasons, this 'sophisticated' forecast system is in widespread commercial use in Florida. Some of the reasons for its success are that there are only about 8 major celery growers, the system is very reliable, growers were able to contract spore trapping to a fledgling technical service (Glades Crop Care) and there are tremendous savings in spray costs. Fortunately the spores are easily identified on spore tapes and since peak spore release is at noon, daily spore tapes may be scanned just once at that time.

An interesting effect of reducing fungicide sprays on celery from 25-40 to less than 10 per season was that, although early blight control was maintained, losses due to Rhizoctonia stalk rot occurred for the first time. Accordingly, growers now adopt a basic spray programme to control stalk rot and apply additional sprays when conditions are favourable for early blight. An important component of the celery blight forecast system is that growers must have excellent control of the disease in the seed beds. By urging this control, the incidence of blight on transplants has been reduced from 20-30% to less than 0.001%

Berger has developed a similar system for Helminthosporium turcicum on sweet corn.

CONCLUSIONS

The main object of the visit was to discuss the practical application of onion disease forecasters that had been developed in and were being used in North America, in preparation for the evaluation of these forecasters in the UK. In this regard the visit was entirely successful and a considerable amount of wasted effort in testing the forecasters should be avoided. Apart from meetings with researchers working on onion diseases, visits were made with scientists involved in many aspects of disease epidemiology, from those working on fundamental studies on the mathematical description of crop disease progress, to those working on the simplification for grower's use, of sophisticated models and sophisticated disease and weather monitoring systems.

It was evident that the opportunities for applying disease and pest forecast systems in North America are much greater than in the UK, not only because of the greater potential for reduced pesticide use and concomitant reduced crop input costs, but also because of the large financial commitment from State funds for research on 'Integrated Pest Management'.

25 June 1990