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Environmental monitoring and disease modelling to minimise chemical usage in vineyards.

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Abstract

This paper reports on the successful integration of an interstate network of environmental data acquisition systems with an expert system. Decisions made by the system can result in minimal usage of chemical pest control methods and can provide effective irrigation strategies.

The expert system developed by the Cooperative Research Centre for Viticulture makes informed decisions about vineyard management based on environmental factors and previous vineyard practices. Environmental data are obtained from approximately 35 collection sites in the south-east of the Australian mainland.

The expert system generates, for each site, recommendations on the need to spray for vineyard diseases. It maintains a data base of vineyard chemicals to assist in the application of chemical control methods. Details of the model design and programming techniques are discussed.

A review of a data acquisition system with special applicability to vineyards and orchards is included.

1 Introduction

Monitoring climatic data in vineyards is an essential step in the timely management of diseases and pests that can cause loss of crop or crop quality. AusVit is a decision support system that uses climatic data for the enhancement of vineyard management practices. Work was done in the eighties on a downy mildew simulator by the South Australian Department of Agriculture. This system was initially to devised to assist advisers predict more reliably the stages of a downy mildew infection. As this system became mature it was proposed that this type of model could be used with enhancements by a broader group of people who required accurate knowledge of disease development in the vineyard.

2 AusVit

AusVit has been developed by the Cooperative Research Centre for Viticulture and has drawn together the expertise of many scientists in the Australian State departments of agriculture, Charles Sturt University and University of Adelaide, and other industry experts. Over a number of years, research knowledge has been accumulated about the strategic management of diseases and pests in Australian vineyards.

AusVit was conceived as an aid to disperse this knowledge more widely into the industry. It combines the original downy mildew model with other biological models including black spot, *Botrytis*, light brown apple moth and mealy bugs. AusVit achieves its aims of reliable production and improved quality of fruit by enabling control measures to be applied more precisely and by reducing the use of chemicals in the vineyard. In addition it provides detailed information on chemicals registered for use in Australian vineyards. It requires as input systematic recording of vineyard details.

2.1 System description

AusVit is a hybrid system that incorporates disease and pest life cycle models, a database and an expert system. The biological models use detailed weather data that has been recorded in the vineyard by automatic data acquisition systems. They monitor field parameters such as rain fall, temperature, relative humidity and leaf wetness. The database is a central component of the system because it enables well-structured recording and reporting of vineyard data, Fig 1. The expert system has been built using the knowledge of many experts and provides the management recommendations for the variety of vineyard scenarios.

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2.2 Implementation

AusVit provides decision support for vineyard managers at many different levels. The three main components of AusVit each gives the user a level of detail that can be further interpreted. The weather data can be summarised and displayed, Fig 2. The biological models use the weather data and give details about disease and pest life cycles and their status in the vineyard. This information is further interpreted to give action statements. Each of these action statements is further explained by detailed textual explanations.

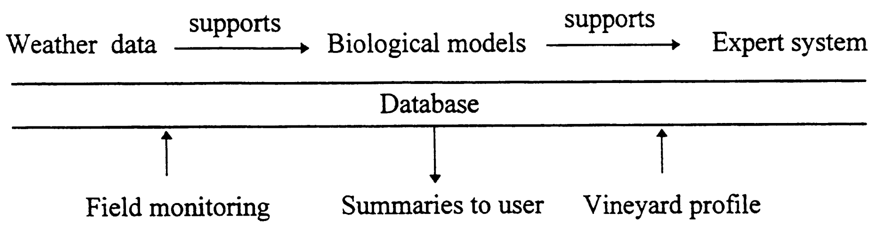

Figure 1: System structure

2.2.1 Weather data

Weather data needs to be accurate and detailed. The data loggers supported by AusVit log at 10 minute or 15 minute intervals. Downloads occur in practice about once a week. During the testing of AusVit it has become apparent that this is the most critical process and that all other processes depend on it if reliable output is to be achieved. It seems that it is also the most error prone. Data loggers that provide quality data need to have good sensors, reliable communications, and be able to be placed close to the canopy of the vineyard.

2.2.2 Models

After the weather data is verified, it provides the basic ingredient for the disease and pest models. Spray cover and irrigations are also used by the models. The models process the weather data using temperature accumulation, leaf wetness times, drying and spore mortality regressions, and can project cycle completeness using long term climatic information provided. Highlights of the individual models are:

1. Downy mildew: primary and secondary infection models with oilspot appearance estimated and calculated. Primary infection considers the zoospore splash conditions that exist during rain periods.
2. Light brown apple moth[3]: day degree temperature accumulation with prediction of lifecycle events based on long term climatic data.
3. Black spot: infection cycles use temperature, leaf wetness and relative humidity.
4. *Botrytis*: uses rain periods to estimate the potential risk.

5. Mealy bugs: temperature and relative humidity accumulation for estimating risk conditions.

Output from the models give clear indications of the current status of the lifecycle of the disease or pest, as in the downy mildew example in Fig. 3.

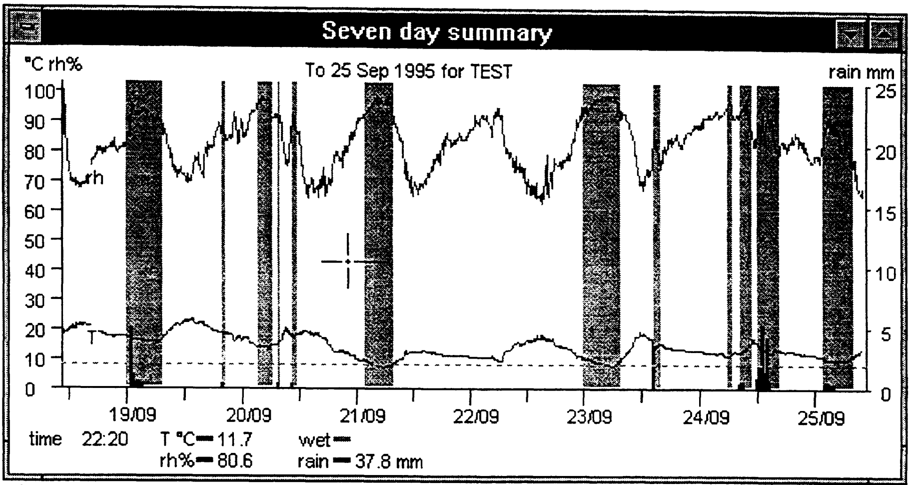

Figure 2: Charting recent weather data

Downy Mildew Infection for CSU Pinot 1996

Infection	Value	Incub.	Oil spots	-died
Pri: 25/09/95 06:40	1.58	100%	05/10/95	

DM sprays applied on this block-
29/09/95 12:00 Pre Inf 10 days cover

Figure 3: Downy mildew infection model summary

2.2.3. Expert System

The expert system is the component that ties together the output generated from the weather and biological models. The expertise contained in the AusVit knowledge base consists of around 300 rules. These rules are able to give educated responses to the facts available about the vineyard. Infection models provide information about the disease development but not how and when it is the most appropriate time to treat symptoms. Experienced managers can make educated judgments. The AusVit expert system gives the manager another educated insight into the problem at hand. Fig. 4 is an example of a recommendation from a consultation with AusVit.

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DOWNY MILDEW: [Apply pre infection]
0 days of spray cover remaining

Despite the oilspots in your vineyard, and the forecast long period of rain, there is little risk of immediate damage from downy mildew. However, a pre-infection fungicide before the wet night is advised to protect the crop from the possibility of further infection and to prevent early leaf-fall.

Figure 4: Downy mildew explanation

During the expert system development the knowledge engineering process involved documenting clearly the current state of the domain experts' knowledge about disease and pest management. Higher level structure diagrams, such as the powdery mildew example in Fig. 5, show the range of attributes required for any decision. These knowledge bases are then described fully by using dependency networks which have been the key documentation technique where the knowledge engineer and domain expert could clearly see the structure and logic of their decision processes. Complete knowledge bases are then validated using a software tool developed for the purpose. Duplications and gaps in the knowledge base are easily identified and fixed within minutes.

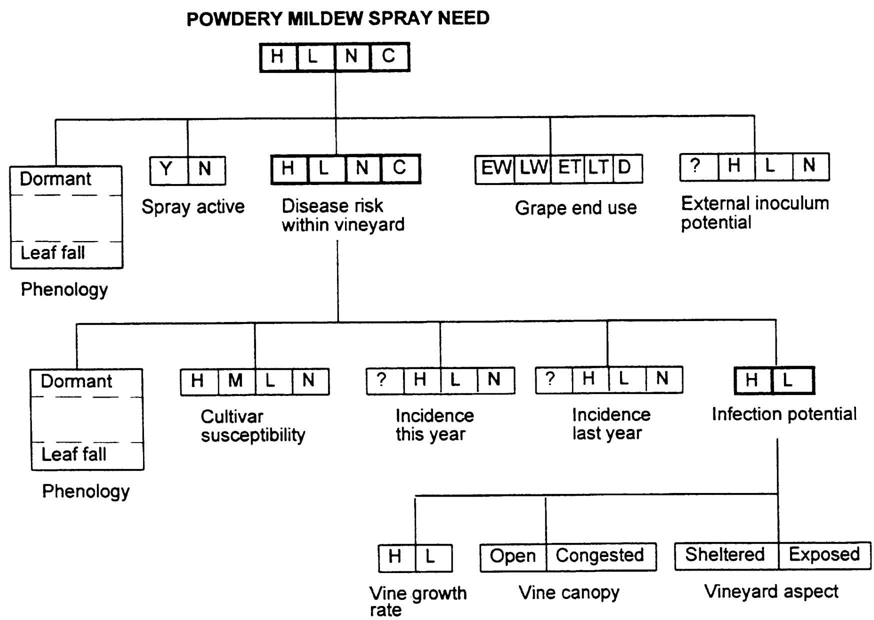

Figure 5: Higher level structure diagram for powdery mildew.

2.2.4. Database

The system is integrated using a relational database. This software provides the main user interface to the whole system. The vineyard profile, spray records, scouting records and irrigation details are all stored in the database from where reports can be easily generated. Other components such as the expert system, models and weather access communicate using dynamic link data exchange or text files containing key data items.

2.3 Software tools

Originally AusVit was prototype using Level5 Object®. This expert system shell provided rapid development times so AusVit could be reviewed by the domain experts as each step was taken in the design process. As the system became more complex it was necessary for it to contain a large number of data entities. Superbase®, a fourth generation language database, was used as the main interface incorporating the previous expert system. Weather data storage, validation and reporting have been done using a C++ program that runs alongside the database. Disease and pest models have been written using C++ because of its good performance and incorporation of legacy C code. The expert system has now been programmed using the CLIPS expert system that is a economic and very capable system used widely in industry. To gain better performance and industry compatibility the database software was changed to use xBase files under the Borland™ Database Engine. Borland™ Delphi® software is now used for the main user interface that controls the other components of AusVit.

2.4 AusVit in practice

The strategic disease and pest management program that AusVit is based on has been tested for a number of years before being presented to the development group of users as a computer program. The agencies involved include the departments of agriculture in major grape growing states of Australia. These trials have produced encouraging results with some cases of about 30% reduction in the number of chemical sprays used during a season against the traditional routine methods.

AusVit also includes a management module that assists in scheduling the timely application of water in an irrigated vineyard. The quality of the fruit can be promoted by using the correct amount of water at the correct times. The practices contained in this module have been tested for a number of years in commercial vineyards in Australia. Testing the computerised system is now in process.
During the 1996-1997 season AusVit is being tested in most Australian States by a total of about 40 vineyard managers and consultants. Some of the

components of the system are in commercial production and the complete system is due for release in 1997.

3. Field Monitoring Techniques

AusVit requires as input, measurement of humidity, ambient temperature, canopy temperature, rainfall, leaf wetness, solar radiation and soil moisture.

3.1 Uniform vineyards

In the majority of AusVit installations the data are collected by, and stored within, weather stations. "Weather station" in this context refers to a self contained data acquisition system consisting of transducers, solar panel, batteries and micro-intelligence for acquiring and storing data. In AusVit installations the weather stations are equipped with modems to permit AusVit access. Weather stations are sensibly utilised in vineyards that do not exhibit climatic variation.

3.2 Microclimates

In some wine producing districts in South East Australia there are vineyards with marked climatic variations within their boundaries. Such vineyards are said to contain microclimates, in this context the size of a microclimate is considered to be several hectare. Microclimates within Australian vineyards occur as a consequence of site preferences. Sites for the smaller or "boutique" vineyards are chosen at higher altitudes to achieve cool climate characteristics, because they are well drained, because they are picturesque and because they have a preferred soil structure. The outcome is often an undulating site that will show climatic variation as a result of layered air temperatures (especially at night), variation in angle of incidence for solar radiation, rain shadowing and soil variability.

There would an advantage if the data supplied to AusVit could be acquired at a microclimate level rather than at a vineyard level. This would enable spraying and irrigation strategies to be optimised for the appropriate sections of the vineyard. It is not economic, however, to install multiple weather stations within a moderate size vineyard.

3.3 Agbus system

The Agbus system was designed to provide an alternative to weather stations and which offers advantages for multiple monitoring and control sites in a moderately sized area. The Agbus system is fully defined and the specifications are in the public domain[8]. It is a bus structured system.

The design philosophy has been to minimise the technological input required from a user to establish and maintain a system. In addition the interface to and action of each software and entity in the system is precisely defined so that a designer can produce a new version of any entity confident that it will integrate into a standard installation.

3.3.1 The Agbus Components

The system components are presented in Fig. 6 and discussed briefly below. Further details can be obtained from other sources[9,10,11,12]. The personal computer, PC, is an IBM or IBM compatible.

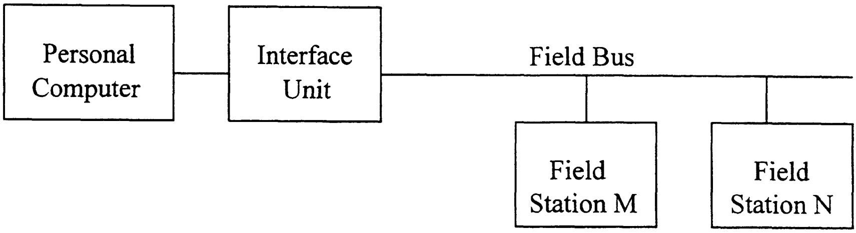

Figure 6: Agbus system components.

3.3.1.1 PC software The PC software can be represented as two layers. The lower layer, or presentation layer, is responsible for interfacing with the field stations through the IFU and field link. It handles all the message format protocol including the error processing. This layer is totally defined by the Agbus specifications. In an MS-DOS environment it is implemented as a terminate and stay resident (TSR) program, in an MS-Windows environment it is implemented as a dynamically linked library (DLL) module. One version of the TSR or DLL (as appropriate) is sufficient for all Agbus installations.

The presentation layer serves as a platform for the application program. The application program is designed to supply features for a particular installation. In the AusVit application it logs data to disc and responds to modem requests.

3.3.1.2 The interface unit The interface unit, IFU, links the PC to the field stations. It interfaces to a serial communication port on the PC. It powers the field stations and modulates and demodulates the bi-directional data to and from the field stations.

3.3.1.3 The field bus For an agricultural application a bus must be physically simple. The Agbus bus is an underground or aerial single twisted pair cable. It is not polarised - it can be connected either way round at any join or junction. The topology is free. The field bus is optically and transformer isolated at the IFU and each field station to lower the risk of lightning damage.

3.3.1.4 The field stations Each field station can monitor a number of sensors and control a number of actuators, these features are application specific and are not detailed in the standard. Each field station contains details of itself such as scaling factors, parameter units and text strings. These details are forwarded to the PC in the initialisation stage. This allows the PC application program to accommodate new field stations without requiring any installation details to be entered by the user. The field station circuitry is not complex, for example a field station that reads eight sensors can be constructed, without using minimisation techniques on 50 mm by 80 mm printed circuit board.

3.3.2 Agbus summary

Because the field stations are relatively inexpensive and easily installed it is economic to monitor microclimates. Because the controlling element at the vineyard is a PC the opportunity exists for bilateral communication, if the AusVit system detects the need to alert the vineyard manager it can supply a detailed warning message on the vineyard PC.

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