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Computer-based Plant Protection Advisory Systems

Copenhagen, 27 - 29 th November, 1991

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PREFACE

Papers presented at the Workshop on Computer-based Plant Protection Advisory Systems held in Copenhagen, November 27-29, 1991.

Computer as a decision making tool in agriculture is gaining importance in the various European countries. Although its use by farmers may be limited, it is expected that in the future more and more farmers will use it to optimize their farm returns since the farm input costs are going up and the prices on farm produce are going down. Furthermore, the public demands on the reduction in the use of farm inputs to protect the environment is bringing in new environmental legislations. Recent studies in Denmark show that 7 % of the Danish farmers with more than 30 ha have a computer and in the next 4 years this figure is expected to raise to 21 %. Thus, development of quality software tools would be required to meet the demands for optimizing the farm returns through reduced inputs.

In Denmark, a computer based plant protection system has been in use since 1985 and improvements are under progress. The goal of the system is to provide an optimal plant protection in terms of pesticide selection and dosage, with the intention of reducing the environmental impact of pesticides. Such systems are not unique to Denmark and similar systems are being developed or used in the various European countries. The success of such systems depends on the plant protection models and the practicality of the system. Development of models requires inter-disciplinary studies and the availability of information. Thus, exchange of information and ideas between research institutions will help in the implementation and improvement of systems in all European countries. In order to initiate the international co-operation on the development and implementation of computer-based plant protection advisory systems this workshop was organized.

The topic of the workshop primarily concentrates on the pests and diseases in agricultural crops and is organized to cover the present status on the computer-based advisory systems, pest and disease models and methods, integration of plant growth and plant protection models, and the future development trends in plant protection in terms of new technology.

We hope that the workshop will provide a good opportunity to discuss and develop strategies for development and implementation of plant protection models and systems. Furthermore, we hope it will also provide a platform for future collaborative projects.

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Workshop on Computer-based Plant Protection Advisory Systems
Copenhagen – 27-29th November 1991

PC-TECHNOLOGY IN PLANT PROTECTION WARNING SYSTEMS IN NORWAY

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ABSTRACT

At NPPI we have developed an integrated advisory system that relies heavily upon the use of PC technology. The main part of the system is the monitoring of diseases and pests done by farmers is their own wheat and barley fields. Plant samples are sent to NPPI together with the field data by mail. Written letter replies are then sent back to each farmer with a detailed recommendation on disease and pest management. 535 farmers participated in 1991. Reports are produced daily summarizing the disease and pest data per county to the extension service in 15 counties. About 90 PC users visited our bulletin board (BBS) with a total count of about 4500 calls during five months. The extension officers' great interest in our BBS is partly explained by the fact that we are distributing two and five days weather forecasts. Also data from some 30 climatic loggers are distributed in our warning system. A voice response system is expected to extend further the interest in our system for all farmers.

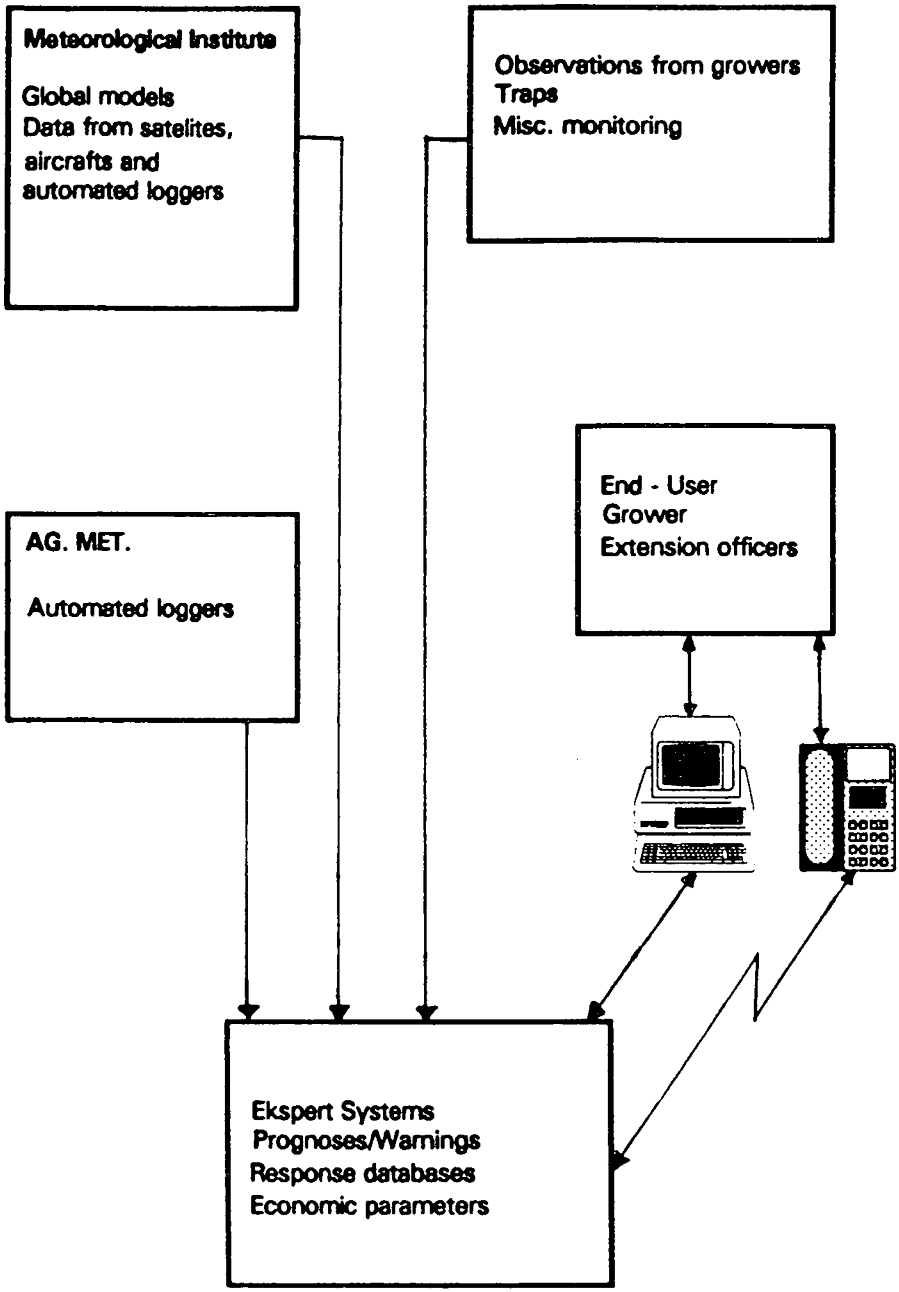
STRATEGY

Our plant protection warning systems are based on the use on PC technology. We find this to be an easy way to achieve important results in a short time. The technology is cheap, and there is a great number of programs, facilities and tools available to take advantage of.

We have on-line communication with about 90 extension offices, research 'rings' and a few private farmers. All these end-users have PC's with modems. The users are served by a PC-based BBS - bulletin board system. This BBS is situated at the Plant Protection Institute, (fig. 1).

Fig 1

Using PC technology in plant protection warning system



We distribute the plant protection programs which are mostly self-developed, to the end users. They in turn can download from the BBS the daily updated pest and disease advices/warnings and climatic data together with weather prognoses. The end users can then use the advisory programs on their own PC's without having to spend very much on telecommunication costs. The alternative would be a central computer (UNIX etc.), and terminal emulation towards this machine. This would give the end users larger telephone bills and less flexibility.

Voice-board based systems have been on the PC-market for several years. We have gained some experience with such applications and started the development of a voice-based system for Plant Protection Advice. This voice-board system will have direct contact with our plant protection databases. It gives updated, spoken plant protection information 24 hours a day to anyone in hold of a modern telephone-apparatus.

A further refining/expanding of our computerbased advisory systems will be the use of Geographical Information Systems (GIS). Electronic geographical maps combining pest and disease warnings/forecasts with climatic data will be used. Our aim is to make this available for the ordinary PC-user, and not to make it an exclusive offer for those with a dedicated workstation. We are considering the use of a GIS application running on PC, which can link this geographical information with our existing plant protection databases.

NORPRE

A warning system for diseases and pests in barley and wheat has been developed over the years since 1982. The main principle is that practical experience and research form the basis of the recommendations given to individual farmers when they present their monitoring results. A system of threshold values has been incorporated into a common database that accurately describes the development of diseases and pests. Relative disease and pest severity is monitored over time, region and crop. From this database daily reports are produced and distributed by telephone lines through our BBS and host server. The disease and pest data are sent by the farmer by mail to NPPI for diagnostics and data entry. The data are processed the day they arrive and replies are sent either by mail or telefax to the farmer as soon as possible. A telephone answering machine is used to record voice messages from farmers to NPPI. This latter procedure implies that no validation of the diagnostics made by the farmer is done before an advice letter is issued. We have also started to build a voice response system where the farmer uses his telephone keyboard to enter his disease and pest countings directly into our database. The advantage of this system is the online character of the input and output. The farmer gets his data processed online and he also gets an oral advice directly. The disadvantage of this system is the lack of possibility to validate the diagnosis before the advice is given.

The number of participating farmers has increased from around 90 in 1982 to approximately 535 this year. The warning system NORPRE is now operational in 15 counties throughout Norway.

The reports are produced daily and next season we expect climatic surveys to be distributed via PC's and the voice response system together with the plant protection summaries. The summaries may in this context be called 'now-cast'.

Our research work is aimed at refining and validating our models for yield loss. Another aspect for our work is to develop a Geographical Information system (GIS) that will typically produce instant maps of the diseases and pests situation for selected counties and crops.

Two booklets have been prepared for the participating farmers. One general overview of the system and service provided and one instruction manual which give fairly detailed in procedural description. Furthermore all farmers are trained in a two hour field meeting at the beginning of the observation period; usually end of May/beginning of June.

MIPS - METEOROLOGICAL INSTITUTE PROGNOSIS SYSTEM

Trough an agreement with the Norwegian Meteorological Institute (NMI) we distribute weather forecasts to the extension offices and The Research Rings. Forty-two hours forecasts are produced twice a day at NMI. The weather prognoses are also downloaded to NPPI twice a day. Five days forecasts are produced and downloaded from NMI to NPPI once a day. The format of the forecasts are PC maps and weather forecasts for some 120 selected locations. The grid resolution of the GIS is 50 km by 50 km for the 42 hours forecasts and 175 km by 175 km for the 120 hours forecasts. The time resolution is 3 hours and 6 hours respectively. The model is based on data coming from NMI, Oslo and ECMWF, Reading, England.

NPPI is distributing weather forecasts by a bulletin board with two nodes and a host server also with two nodes. Some 90 PC users throughout the country may access the systems on a 24 hour basis. Programs are updated and distributed to the PC users. The data transfer is accomplished by fully automated routines. In fact, some users use a program facility to transfer data during the night. Time of connection has been preselected or proposed by us to smooth the traffic load.

MONITORING THE CLIMATE IN AGRICULTURAL AREAS BY CLIMATIC LOGGERS

In 1988 a national program was launched to deploy 40 automatic climatic loggers. The loggers cover the most important agricultural areas. The equipment we chose was Campbell loggers (CR10). The parameters measured every 10 minutes and recorded every hour include: temperature 2m height, three different soil temperatures, relative air humidity (2m height), wind speed (2m), solar radiation, leaf wetness (2m height) and summer precipitation.

The loggers are all online via telephone and data from all loggers are automatically collected every morning. The data are validated using standard programs that will mark unexpected measurements before appending the new data to existing databases. Graphic programs have been developed that allow easy retrieval and displaying of climatic history for the current year. The daily updated data are distributed via our bulletin board and host server on a 24 hour basis. The end user may also easily retrieve climatic data for the last 24 hours, last 5 days and the last 30 days.

So far 16 stations have been deployed; three more will be operating by the end of this year. By the end of 1993 a total of 40 stations will be online. Another 12 stations of a different make exist at the experimental farms. Work is in progress to combine the data from the two sources.

OTHER ACTIVITIES

At NPPI and The Experimental farm Ullensvang at the west coast warning systems in fruits have been developed that use special electronic devices to record selected weather parameters. Results from this monitoring are distributed by fax to extension officers and fruit growers.

Late blight of potato is another topic that is studied. Late blight warnings will be incorporated into a unified plant protection warning system.

CONCLUSIONS

The BBS concept has great potential. It gives us the possibility to create a 'market-place' where farmers, agricultural advisory personnel, and - eventually - commercial companies can exchange ideas, experience and give advice. The time might not be ripe for many people yet to accept the idea of 'chatting' with a computer, but this may change rapidly in a few years.

Some questions will arise: Is PC-technology secure enough, is it fast enough and can it cope with large amounts of data? So far, we have available PC-technology that can handle the present amount of data in a secure and efficient way. If or when the amount of data will bring our systems to kneel, the efforts invested in developing our PC applications may be safeguarded by upgrading our applications to other platforms.

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STATUS ON THE COMPUTER-BASED PLANT PROTECTION SYSTEMS IN DENMARK

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ABSTRACT
There are eight computer-based plant protection systems in Denmark. These are developed by the Research Centre for Plant Protection (RCPP) and six private firms. The systems developed by the RCPP are for farmers having and not having computers. Farmers without computers can use the relational database system by communicating either through post or by audiotex. For farmers with computers, the software is available through the Danish Agricultural Advisory Centre. In both these systems, the same recommendation model is used and it takes into account the actual field situation in the evaluation and recommends reduced dose of pesticides. Systems developed by the private firms are primarily for planning pesticide spraying or lookup tables for pesticides. Four of these systems are commercially available and two are for the internal use by the firms.

KEY WORDS: PC, computer, plant protection.

INTRODUCTION
Recent study by the AIM-Farmstat show that, in 1990, 7 % of the Danish farmers had a computer and by 1994 16 % of the farmers would own a computer. Thus, computers as a farm management tool has a large potential in Denmark.

Development of software, specific to plant protection, has been initiated both by the Research Centre for Plant Protection (RCPP) and private agencies. RCPP's software's are primarily developed to investigate the possibilities for implementing the Centre's plant protection recommendation procedures. The software developed by the private firms are of commercial purpose or for the internal use by the firm. There are in all eight software systems. Common to all of these systems are that they are MS-DOS based programmes.

PLANT PROTECTION SYSTEMS AT THE RESEARCH CENTRE

The strategy for development of computer-based systems at the RCPP has been directed toward fulfilling the needs of both the farmers having and not having computers. For farmers without a computer, a system for monitoring and control of pests was initiated in 1983 and in 1987 a relational database system was developed and implemented (Murali, 1990). The farmers would send in the field observations by post or telefax and would receive in reply recommendations and the regional and the national statistics on the pest status, together with the next field registration card. Field registration and recommendations continues through most of the growing season. The system covers field crops such as barley, wheat, sugar beet, field peas and carrots. In 1991, an audiotex (voice response) system using touch-tone telephone was tested and the success of the system has initiated in the conversion of the entire postal system to audiotex system (Audiotex system is presented else where in this proceedings).

In 1987, an information system for plant protection was initiated and the recent field test of the system has show encouraging results (Murali, 1991; Secher, 1991). The system is intended for use by farmers and agricultural consultants with computers. The system includes plant protection recommendation models and information on pests, diseases, beneficial organisms, pesticides and spraying techniques. In both the postal and information system, the evaluations are based on the actual field situation and the field and weather factors, and reduced dose of pesticides are recommended. The information system will be implemented and marketed by the Danish Agricultural Advisory Center.

COMMERCIAL PLANT PROTECTION SYSTEMS

There are four commercially available plant protection systems. At present, the only system which takes into account the actual pest situation in the field for evaluating the recommendations is marketed by the Danish Agricultural Advisory Centre (Department of Plant Production, Udkærsvej 15, DK-8200 Århus N). The software was developed in co-operation with the Research Centre and includes the plant protection recommendation models developed by the Research Centre. The system is called the "PC-Plant Protection" and the present version includes only weed control. The forth coming version, which is due for release in April '92, will also include pest and disease control. The software is available as an independent module or as an integrated package called "The Integrated Farm Management System" which contains modules for field management, fertilizer planning, irrigation scheduling, farm accounts, mark machinery and animal husbandry. Some of these modules are available in English and Swedish.

The three other softwares are primarily tools for planning plant protections and these does not provide any means for evaluating the pesticide requirement based on the actual field measurements. These softwares can be considered as specialised spreadsheet programmes. The farmer must know before hand what pesticides to use and when in planning the spray schedule. These softwares include also field log.

"Næsgaard Mark" (Landbrugets Data Systemer, Søborgvej 3, DK-4850 Stubbekøbing) is a modular system with programmes for farm accounts, farm planning, fertilizer planning and animal husbandry. Farm planning module which includes pesticide spray is available in English and Swedish.

"CONSUS-markstyring" (Dansk Landbrugs EDB, Sønderagervej 21, DK-6670 Holsted) is primarily a planning program for spraying, fertilizer application, farm mechine allocation and farm management. A new module for plant protection is expected to be released by January '92, which would recommend control measures with reduced pesticide dose, taking into account the actual field situation. The initial version will include only weed control. The module is developed in co-operation with the pesticide firms.

"Bruger-Data Markstyring" (Bruger-Data EDB Aps., Lundevej 1, 5580 Nr. Åby) is also a farm planning program with modules for spray scheduling, fertilizer application and field log. The system is available also in Swedish and under UNIX operating system.

PLANT PROTECTION SYSTEMS FOR INTERNAL USE

There are two plant protection systems which are developed for internal use by the firms - Shell (Shell Kemi A/S, Kongensgade 113, DK-7000 Fredericia) and DLG (Danish Co-operative Farm Supply, Axelborg, Vesterborgade 4A, DK-1503 Copenhagen). These software tools are for use by their sales representatives and are database systems for referencing pesticides from the pesticide tables. These are more like pesticide handbook and does not take into account the actual field situation in the assessment of pest, diseases or weed control.

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PRESENT STATUS OF COMPUTER-BASED CEREAL DISEASES PROTECTION SYSTEMS IN SPAIN

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ABSTRACT
It has been estimated that some 50 different pathogens attack economic cereals in Spain; 22 are known to attack barley, about as many attack wheat, 16 are known to attack rice and 12 attack corn. The most important ones infecting barley are Powdery mildew, Helminthosporium leaf spots and Fusarium stem-base rot; those for wheat include Septoria leaf blotch, leaf and yellow Rusts and Fusarium stem-base rot. Common smut and Fusarium stem and root rot are prevalent on corn; Blast and Blight are the most important rice diseases in Spain. Little is known about epidemiological and economic aspects concerning these diseases; nevertheless, some information is summarized about disease forecasting, crop loss assessment and economic thresohld of treatments. Finally, a simple programme (SEPCONT) is presented, which uses empirical or mechanistic submodels for disease forecasting and recommendations for chemical control of Septoria leaf blotch in wheat.

KEY WORDS: cereal, disease forecasting.

INTRODUCTION
In 1990, the total area devoted to cereals in Spain was 7.789 Mha, of which 4.490 Mha were barley, 2.243 Mha wheat, 556 Mha corn and 80 Mha rice.

During the last five years, the mean grain yield from barley has been about 2.800 kg/ha, 3.300 kg/ha from wheat, 6400 from corn, and 6.200 kg/ha from rice (Anonymous, 1990).

The wheat hosts in Spain are primarily winter bread wheat (*Triticum aestivum* L.), cultivars "Anza" "Talent" "Marius" and "Rinconada"; the most widespread of the barley (*Hordeum vulgare* L.) cultivars are spring cultivars such as

"Zaida" and "Kym", and winter cultivars such as "Dobla" "Albacete" and "Reinette". Rice (*Oryza sativa* L.) cultivars type "Japonica" such as "Bahia" "Tebre" "Betis" and "Senia" are prevalent against those of the type "Indica". Corn (*Zea mays* L.) hybrids cycle 400 to 800 are sown according to climate characteristics.

Often all of the cereals have grown after a previous cereal crop. Such intensive production would be expected to increase many disease problems, but in practice diseases have been contained, mainly by a combination of dry weather and fungicide use, and seldom by use of resistance.

Except for limited individual reports a summary of the principal cereal diseases in Spain has not been published up till recently (Marin, 1979, 1985a, 1986a, 1986b; Marin and Aguirre, 1985; Marin and Jimenez, 1981a, 1981b, 1982a, 1982b, 1984; Marin et al, 1990). Epidemiological aspects of some cereal diseases related to economic ones were not published up till 1985 (Marin, 1985b, 1987; Marin and Mansilla, 1989; Marin et al, 1990). A spray program (SEPCONT) based on disease forecasting (Septoria leaf Blotch/bread wheat) was elaborated with 16 years data and presented for use in the year 1988 (FUNDESCO,1991).

Studies and surveys with summary purposes were conducted primarily in two of the major cereal growing areas, that is, in Andalusia and Catalonia (southern and northeast Spain respectively), both growing cereal regions with a similar cereal pathology.

Of all the pathogens causing aerial diseases, *Erysiphe graminis* DC.f.sp.*hordei* Em. Marchal, *Drechslera teres* (Sacc.) Shoem. and *Bipolaris sorokiniana* (Sacc. *in* Sorok.) Shoem. in barley; *Septoria tritici* Rob. *ex* Desm., *E. graminis* f. sp. *tritici*, *S. nodorum* Berk., *Puccinia striiformis* f.sp. *tritici* Wensted and *P. recondita* f.sp. *tritici* Rob. in wheat; *Ustilago zeae* (Beck.) Unger, and *Fusarium moniliforme* Sheld. in corn; and *Pyricularia oryzae* Cav. and *B.oryzae* (B.de H.) Shoem. in rice, were the most prevalent ones in the above mentioned regions. Some of the prevalent stem-base pathogens were: *Fusarium culmorum* (W.G.Smith) Sacc., *F. graminearum* Schwave, and *Gaeumannomyces graminis* (Sacc.) Arx *et* Olivier in wheat and barley; *F. graminearum* in corn; and *F. culmorum* , *F. semitectum* Berk. *et* Rav. *in* Berkeley and *Pyricularia oryzae* in rice. Pathogens such as *Heterodera avenae* Wollenw., BYDV, in wheat and barley; *Pseudocercosporella herpotrichoides* (Fron) Deighton and *Rhizoctonia cerealis* Van der Hoeven in wheat; MDMV in corn, and *Sclerotium oryzae* Catt. in rice, occurred sporadically in scattered locations.

Fungicides for the control of aerial or stem-base diseases are used on the majority of cereal crops (barley, wheat, rice) with treatments being applied therapeutically when the symptoms are obvious. Prophylactic treatments are seldom applied and usually without epidemiological predictive knowledge. "MBC" fungicides (benomyl, carbendazim and thiophanate methyl) alone or in combination with dithiocarbamates or "Triazoles" fungicides (triadimefon and propiconazole) and the related prochloraz and fenpropimorph have become prominent for the control of leaf or ear barley and wheat diseases. Propiconazole, benomyl and triziclazole are fungicides used to control rice diseases (Marin,1985b, 1987; Marin et al, 1986a, 1986b).

Occasional severe epidemics (42 - 46% yield losses) caused by *S. tritici* occurred with p=0.1 probabilities in Catalonia and p=0.2 in Andalusia. Severe epidemics (20 - 60% yield losses) caused by *Pyricularia oryzae* in rice occurred with p=0.2 probabilities in Catalonia and p=0.3 in Andalusia; and epidemics caused by *E. graminis* f.sp. *hordei* in barley associated with yield losses of about 18 - 40% (estimated through "single culms") occurred with p=0.2 probability in Catalonia.

To avoid these occasional yield losses, some growers usually spray the barley and wheat crops once or twice, and rice 1 to 4 times.

Using the simple "Decision-Theory" approach (McLean et al, 1986, pg. 2-9) the 1 to 2 control strategy resulted economic when low cost fungicides were used (Marin,1985b,1987;Marin and Mansilla, 1989; Marin et al, 1986, 1987, 1990).

In that situation (with low occurrence probabilities for severe epidemics) forecasting methods would be valuable to reduce occasional serious losses when favourable conditions for disease occur. For that purpose SEPCONT was developed (FUNDESCO, 1991). It is a wheat Septoria leaf blotch spray programme based on disease forecasting and on empirical criteria for control.

This paper summarises the present status of epidemiological knowledge and computer-based cereal disease protection systems in Spain.

EPIDEMIOLOGICAL BASES OF THE CONTROL

At present, as far as I know,information about cereal disease epidemiology, crop loss assessment and forecasting systems in Spain can be summarized as follows:

Table 1. Equations to estimate disease progress.

disease	host/cultivar	equation
Blast-leaf	rice/"Ital-Patna"	y'=0.1646*t-6.087
	"Veneria"	y'=0.0704*t-5.587
	"Bahia"	y'=0.0514*t-5.780
	"Betis"	y'=0.0523*t-6.699
	"Senia"	y'=0.0311*t-5.177
Blast-panicle	"Veneria"	y'=0.0398*t-4.052
	"Bahia"	y'=0.0807*t-3.700
	"Betis"	y'=0.2190*t-6.013
	"Senia"	y'=0.0721*t-2.579
Powd.mild.	barley/"Matnan01"	y=1/(1+65.01* *exp(-0.1047*t))
Septoria	wheat/"Torin"	y=1/(1+35.54* *exp(-0.0509*t))
	"Cajeme"	y=1/(1+78.15* *exp(-0.0599*t))
	"Anza"	y=1/(1+52.43* *exp(-0.0525*t))
	"Arganda"	y=1/(1+104.6* *exp(-0.0573*t))

y'= logit(y); y= severity proportion;t = days.
Epidemic models for favourable conditions.

Equations proposed in Table 1, were previously published (Marin, 1987; Marin and Aguirre, 1986; Marin et al, 1986,1987) except for barley Powdery mildew.

Equations proposed to estimate yield losses caused by some cereal diseases are summarized in the Table 2. They were obtained from experimental data and previously published (Marin, 1985b, 1987; Marin and Mansilla, 1989; Marin et al, 1990) except for barley Powdery mildew.

Table 2. Equations to estimate yield losses.

disease	host/cultivar	equation
Blast	rice/"Krisna"	P=1.5154*S-3.9054
	"Bahia"	P=1.6455*S-5.1512
Septoria	wheat/"*"	P=-3.88+0.23*Sf+ +3.8*10^-3*Sf^2
Powdery mild.	barley/"Matnan01"	P=-0.267+0.068*Sf+ +0.0089*Sf^2

P= yield loss(%);S=panicle severity(%);Sf= mean severity(%) on four top leaves."*", wheat cvs. mentioned in Table 1.

Equations proposed for disease forecasting are included in Table 3. These equations were published in the same papers as cited for Table 2.

Table 3. Equations for disease forecasting.

disease	host	equation
Blast	rice	PI'=1.5493-0.0299*t
		Sf=33.65*x+0.1226
Septoria	Wheat	Sf=662.31-213.07*T+ +17.30*T^2
		Sf=-257.60+297.88*R- -64.26*R^2
		Sf=-207.82+33.66*T+ +2.35*R
		Sf=106.89-4.39*DP+ +0.0483*DP^2

PI'=log(PI);PI= incubation period;t=days of weather favourable for disease development; Sf= foliar severity(%);x=number of captured conidia; T= mean temperature from GS"first node visible" to GS "ripening", when symptoms are obvious (Sf=1%) at the first GS cited;R= rain (mm/day) during the above mentioned period;DP= dry period, during the above mentioned period. Equations refer to the cvs. in Tables 2 and 3.

SEPTORIA SPRAY PROGRAMME (SEPCONT)

Septoria leaf blotch caused by *S.tritici* in wheat is sporadic but could potentially cause a level of up to 46% yield loss.

Growers typically initiate spraying when symptoms are obvious at the GS "first node visible" (about February 20th). If they can't see symptoms or if they hope for dry weather, treatment fungicides are applied if severity on three top leaves, at GS "boot-heading", is about 5% or more.

SEPCONT is a BASICA programme designed for the winter wheat/*Septoria tritici* /dry growing area pathosystem but it should be applicable to epidemics caused by *Septoria nodorum* in the same areas and cultivars. It has basically three menus. All menu options were numbered below.

Menu 1.- 1.1 Explanations.
1.2 End
1.3 To continue.

Menu 2.- (from 1.3)
2.1 Observation before GS "first node visible":A
2.2 Observation after GS "first node visible":B
2.3 Dir. and Files.
2.4 Menu 1
Esc to Quit

Menu 3.- (from 2.1 or 2.2)
3.1 Imput data.
3.2 Output data1.
3.3 Output data2.

Imput data example (option A):
Date of observation: 02/20th/91
Cultivar: Anza
Growth stage: first node visible.
Meteorological data from date of observation to May 20th (or to GS "ripening"):
minim. mean temperature (ºC): 8 dry period (days): 12
precipitation (mm/day): 2
Crop data:
expected yield (kg/ha): 3600
yield price (ptas/kg): 26
severity estimated (%): 1
Treatment data:
treatment cost (ptas/ha): 3300

Output data example (Option A):

parameter to forecasting	T	DP	R	T+R
severity(%)	65.0	61.2	81.2	66.2
yield loss(%)	27.3	24.5	40.1	28.2
losses(ptas/ha)	24802	22335	36457	25638
recommendation	treat.	no treat.	treat.	treat.

T,DP,R as in Table 3.

Recommendation based on U.E.T.(Ecomonomic Threshold of Treatment); this is obtained from:

PCT1=4.5230-0.9309*S+0.0128*S^2
(for fungicides type propyconazole)

and

PCT2=20.6753-0.4257*S+0.0098*S^2
(for fungicides type captafol)

S= residual severity (%)= severity not controled by treatment fungicide, evaluated at GS "ripening".

If forecasting severity > U.E.T(<> S from PCT1 or PCT2) treatment is recommended.

S from PTC1 (or PCT2) was obtained after manipulating equations such as:

PCT1'= -0.9309+2*0.0128*S=0

S=0.9309/0.0256=36.36 %; that is the severity <> U.E.T. for propyconazole type fungicides.

Option B is based on severity an precipitation during the week before data of observation, and is not exemplified here. That is justified because "Option A" requires information in advance about precipitation and temperature and such information becomes a serious limitation to forecasting disease severity and losses; in fact, it is the major uncertainty in the programme.
SEPCONT accurately predicted disease and losses in experimental plot (considering a range of climatic data) in Andalusia and Catalonia for several

years. Currently, research is being conducted to test and modify the models for other locations and cultivars.

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CURRENT AND FUTURE STATUS OF COMPUTER-BASED PLANT PROTECTION ADVISORY SYSTEMS IN THE UK

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ABSTRACT
The current use of 'live' computer-based plant protection systems for arable crops in the UK is reviewed. The use of 'singleton' pest or disease simulation models on centralised computer facilities is described briefly. Two PC-based expert systems and two PC-based simulation models are also included. Singleton systems under construction in the short term future are listed but in the longer term future development of pest and disease simulation models or expert systems should, ideally, be integrated into whole farm computerised management systems so that common meteorological, agronomic and economic resources may be shared. Future considerations should include mutual co-operation between biologists and system developers across all EEC and EFTA countries in a forum that ensures funding to maintain the current interest and impetus in this subject which will contribute significantly to reducing pesticide usage.

KEY WORDS: Plant protection, computerised-model, expert system, advisory services.

INTRODUCTION
This paper is essentially a brief review of the current status of computer-based crop protection advisory systems currently available, although not necessarily in use, for arable crops in the UK. It also reviews briefly the current potential for descriptive modelling as well as computer-based modelling of pest and disease development. The author has 'surveyed' the range of available and potential applications as comprehensively as possible but this review is by no means exhaustive and apologies are made to those biologists whose work has been omitted.

Systems currently available for advisory purposes in the UK are either expert systems or those based on relatively simple development or simulation models related to meteorological variables. Whatever the complexity of these systems they all attempt to aid decision-making on only one pest or disease in isolation. However this statement is made not to denigrate such systems. Instead it is made to illustrate the need for integrated systems for pest and disease and possibly weed control initially in a single commodity, for example, winter and spring cereals. If such systems are to be adopted extensively and used successfully, either directly by farmers or, preferably, indirectly by advisory services or commercial consultants then all the decision-making processes will need to be fully integrated. This will facilitate the shared use of common resources of, preferably, local meteorological data and all agronomic and economic factors likely to influence such processes. Systems must meet the farmer's needs even if the output from them is interpreted by an adviser/consultant. Certainly computer-based systems are likely to be unsuccessful if introduced to the farmer without adviser/consultant support. Moreover the use of computer-based systems for the wrong reasons will destroy their credibility and farmers belief in their value to his enterprise.

Ultimately a whole-farm computerised management system may be the goal with complete integration of all decision making support systems. Clearly such a system could be very complex and may not be justified economically. Furthermore decisions on the need for the control of certain crop problems now and in the future may not be required because treatment would rarely, if ever, be cost-effective. However other decisions, that have hitherto been disregarded because prophylactic treatments were invariably cost-effective, will need to be made more carefully and will justify the development and validation of models and computer systems to assist in making the best choice from available options.

HISTORICAL PERSPECTIVE IN THE UK

The use of computer aids in crop protection was the subject of a single session at the British Crop Protection Conference (BCPC) – Pests and Diseases, held in 1984 (BCPC Publications, 1984). Seven lectures and eight poster papers were presented at the conference in the UK which represents what may become practical reality in the near future as well as reviewing the latest developments in crop protection practice in the UK. Since 1984, however, there appear to have been limited advances in the construction and application of pest and disease models or computerisation of such models in the real world of crop protection advice. Of the systems presented in the session at the 1984 BCPC only one has undergone readily apparent and further redevelopment leading to a tangible product available to the agricultural industry (Mann & Wratten, 1991) to assist in the decision-making process. Even this product is by no means perfect and would benefit from further enhancement in the light of comments received from other expert entomologists (Wratten, pers. comm.).

Admittedly few of the papers in the session at the 1984 BCPC were concerned with the development and computerisation of models but this may have been a reflection of the state of the art at that time. However, other uses of computers in crop protection were addressed. Several were concerned with the technology of measuring meteorological and epidemiologically significant variables as well as data storage and presentation. The use of EPIPRE in the Netherlands and its potential for commercial use in the UK were reviewed but this system appears to have few if any users now in the UK. In 1984 videotex in the form of Prestel Farmlink, ICI Agviser and Counsellor appeared to offer relatively inexpensive access to potentially useful computerised aids to decision-making in crop protection but these systems were abandoned in the mid to late 1980's because the number of subscribers was insufficient to justify the central support required.

CURRENT DEVELOPMENTS

Computer-based simulation models or expert systems that are currently available in the UK are either PC-based or reside on a central mainframe or mini-computer facility. Squire and Hamer (1990) have compiled a UK register of agricultural models, many of which have been translated into a computerised system. Fifteen of the models listed are concerned directly with pest and disease problems in arable crops although few of these are listed as currently available for use by advisers and consultants. Other models are also listed for pest and diseases of vegetable and fruit crops.

In terms of day to day use for advisory purposes the Agricultural Development and Advisory Service (ADAS) in England and Wales currently relies almost entirely on the output from just three systems. The first known as HERDS is run daily on the Meteorological Office's computer. The system has been described by Roe (1984) and it remains essentially the same today, except for a modification to the output for potato blight risk, as it was in 1984. In addition to providing the meteorological data for the past 24 hours the system calculates the degree of infection risk for the pathogens that cause wheat and barley leaf blotch (*Septoria tritici* and *Rhynchosporium secalis* respectively), barley mildew (*Erysiphe graminis* var. *hordei*), eyespot (*Pseudocercosporella herpotrichoides*) and potato blight (*Phytophthora infestans*). Clearly the degree of infection risk is a useful indicator of the likelihood of disease development but HERDS was never designed to indicate the need to apply a fungicide or the timing of such a spray to control a particular disease.

In contrast the peamoth and cutworm development programmes (CWDEV) that run on the Ministry of Agriculture, Fisheries and Food's (MAFF) central computer facility at Guildford provide a reasonably accurate guide to the timing of an insecticide spray to prevent further development of the larval stages of *Cydia nigricana* and *Agrotis segetum*. The models upon which the computer programs are based have been described by Blood-Smyth (1983) and Bowden et al. (1983) and require the input of daily maximum and minimum temperature and rainfall. The output from both HERDS and CWDEV requires interpretation by ADAS advisers before the information derived is sent to farmers who subscribe to ADAS services.

In Scotland and Northern Ireland the state advisory services currently make little or no use of computer-based systems for decision support on pest and disease control.

PC-based systems that are currently available in the UK are two expert systems, Grain Pest Adviser (Anon, 1991) and Wheat Bulb Fly (Jones *et al.*, 1990) and an interactive computer-based advisory system based on simulation models of winter oilseed rape summer pests and cereal aphids. The model for the latter has been described by Mann & Wratten, (1991). The model for the summer pests of oilseed rape was constructed from published biological data on pollen beetle, seed weevil and pod midge. (Wratten, pers. comm.)

Grain Pest Adviser is a computerised expert system that provides information and advice on pests of stored grain in commercial stores in the UK. It can be used for: problem solving, financial analysis, strategy advice and information. The system was developed jointly by the Centre for Pest Management, Imperial College, University of London and MAFF Central Science Laboratory, Slough.

BULBFLY is a computer-based expert system developed for the management of wheat bulb fly and provides recommendations on strategic and tactical options including comparative costs of treatments, ecological and biological information on the pests, details of cultural control and advice on the safe use of pesticides. It was developed by the Centre for Pest Management, Silwood Park and ADAS.

A very limited number of copies of the two expert systems have been sold to date. Both are currently being up-dated and will need much more thorough exposure and marketing to reach the desired user-audience. The cereal aphids and oilseed rape pests system has been 'test-marketed' as the Hoechst Computerised Advisory Programmes free to distributors and to selected farmers during 1991 by Hoechst UK Ltd. The system aims to provide an easy and practical way of calculating the cost of pest attack and takes account of agronomic and financial details of the crop plus pest infestation levels. Advice is given on the need to spray or the need for a later review of pest infestation. The system has also been available on videotex within the company/distributor network for at least two years. Hoechst will be assessing their customer reaction during this autumn and winter.

Models varying from the most simple to those of considerable complexity have been designed and published in scientific journals but have yet to be translated into a computer-based system. In addition there appears to be a wealth of information and data available, as yet unpublished which could be translated into models. Indeed several entomologists and plant pathologists either singly or in groups in the UK are at the stage of model construction but clearly it will take several years before such models are completely validated and ready for translation into a computer-based system. The development of models has been cited in the register compiled by Squire and Hamer (1991) or details of the work have been personally communicated to the author. Currently work is in progress to develop descriptive or simulation models or expert systems for the following:

- Leaf diseases of brassicas (applicable to oilseed rape)
- Diagnosis of sugar beet diseases and disorders
- Potato virus Y in home saved potato seed
- *Aphis fabae* infestation of field beans
- *Septoria tritici* in winter wheat
- Spring aphid populations
- Aphid biology and barley yellow dwarf virus
- Cereal and fungal growth
- Population dynamics of potato cyst nematodes
- Population dynamics of cyst nematodes

- Validation and modification of models and forecasting schemes for leaf and stem base diseases of major arable crops in the UK.
- Cereal take-all
- Potato aphid population development
- Sugar beet aphids and virus yellows
- Pea aphid
- Slugs on winter cereals

FUTURE PROSPECTS

Clearly there is a growing awareness of the potential to utilise information technology to improve the interpretation and presentation of data relating to pest and disease development and hence improve the certainty with which advice may be given and acted upon. The wealth of data already available needs to be digested and translated into verifiable models and/or prototype expert systems for which development is justified. This needs to be done as quickly as possible if only to identify the omissions in former and current research and the gaps in present knowledge. Only then will it become apparent exactly what further experiments are required to obtain the missing data. One of the major problems with disease simulation models is how to 'prime' the system, that is how to make objective assessments of current disease levels or the level of inoculum of the pathogen. Rapid visual assessment methods need to be established and for the less easily assessed diseases eg eyespot and septoria of cereals, serological techniques may assess inoculum or the stage of disease development more reliably in the future. Priming of pest models with initial pest and natural enemy population sizes also presents a difficult problem that may require a unique solution which is dependant on the biology of the various species involved in each case. Detailed research into the:

(i) use of trapping and visual assessment techniques that account for migration of pest and natural enemies into crops over an extended time period
(ii) spatial distribution over whole fields (or regions)
(iii) problems associated with accurately assessing the relatively low numbers of individuals entering or present at this point on the population dynamics curve is an essential pre-cursor to model development.

The temptation to offer a simulation model or expert system to the agricultural industry at the earliest opportunity, simply because scientists are now required to meet commercial targets, should be resisted. Thorough testing and a review of the product undertaken by experts who are currently outside the project, should perhaps be a pre-requisite of model or system accreditation. The involvement of or sponsorship of the system by a commercial company, with potential benefits from its use may create problems of impartiality.

In fostering significant reductions in the pesticide burden on the environment computer-based plant protection advisory systems offer an effective tool for complementing both advisory services and commercial consultants. Even the most comprehensive computer-based systems will never replace the experienced adviser/consultant. Instead they should be used to augment what is available by providing powerful processing capability, especially where multiple decisions are required simultaneously. Comprehensive and fully tested systems should ensure that no factor has been omitted in the increasingly delicately-balanced equation of cost-effective and more environmental-frendly pest and disease control.

In the light of the growing interest in simulation models pest and disease biologists should be encouraged to offer their models/systems for testing and validation across the whole of Europe and elsewhere. They should also be encouraged to use similar or compatible operating environments and languages. Intellectual property will need to be protected carefully and any modifications required to the system in various countries agreed with the originators of the model or system. The EEC should create a forum for the exchange of models and systems so that this important area of pest and disease modelling and computerisation of simulation models, particularly with respect to diseases, and expert systems will benefit from the mutual international co-operation of biologists.

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BAVARIAN CONCEPT OF ENVIRONMENT-COMPATIBLE PLANT PRODUCTION

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ABSTRACT

In Bavaria a network of about 120 meteorological stations has been established. Weather data together with actual field data are the basis for EDP-supported decision models, which are being developed, tested or already operated in practice.

These models concern wheat diseases, barley diseases potato blight downy mildew of cucumber, apple scab, and rape pests.

KEY WORDS: Meteorological network, EDP-supported decision models.

INTRODUCTION

The environmental effects of pesticides, organic manure and mineral fertilizers are increasingly the topic of public discussion. With regard to fertil ization the discussion was triggered off by high nitrate contents in the ground water. In the last years traces of pesticides were found in the ground and drinking-water, too.

Further problems result from the economy. The prices for agricultural products are declining, while those for the input are constant or increasing.

The severe legal regulations to minimize negative effects on man, animal, ground-water and ecosystems demand an environment-compatible plant production.

The Bavarian Ministry of Food, Agriculture and Forestry therefore developed the program "Environment Compatible Plant Production" in 1989. This program is a supplement and a refinement of the concept of "Integrated Plant Production", which has been recom mended by the Bavarian advisory service since 1977.

Within this program special emphasis is laid on increased data collection, modern advisory systems and computer supported advice to provide better recommendations for the application of fertilizers and pesticides.

METEOROLOGICAL STATIONS

The practical use of this program requires the recording of current weather data and detailed field data, which are the basis of decision models.

The meteorological network of the German Weather Service with 18 main stations in Bavaria is very wide-meshed and does not cover the different climatic regions with differing types of soil. The meteorological data of this network actually are not available for our advisory service.

Therefore a network of about 120 meteorological stations all over Bavaria has been established by the Ministry of Agriculture within the last three years, which collects current data relevant to plant production.

The aim of this network of meteorological stations in agriculture is to get exact weather data all over the country for decision and forecast models. The distribution of these stations in Bavaria was determined due to the topography, the main agricultural productions areas, the geological aspects, the different soil types and the climatic conditions.

100 stations are installed on private farms and 20 stations are established in State Institutes for Soil Cultivation and Plant Production and for Vine and Horticulture as well as in state farms.

The station itself is in state property. Farmers have signed a contract containing the conditions of installation and operation. They have to provide the Personal Computer (PC) and the connection to videotex by themselves. Costs arising by videotex sessions and utilization of the PC for the transmission of weather data from the PC on the farm to the host computer installed at the Ministry of Agriculture are refunded to the farmer by an overall compensation.

The station contains the following sensors for recording:
- air temperature at 2 m and 20 cm above surface (°C)
- soil temperature at 20 cm below surface (°C)
- wind velocity at 2,5 m above surface (m/second)
- global radiation at 2 m above surface (Watt/m^2)
- relative humidity at 2 m above surface (%)
- rainfall (heated) (mm).

Stations for hopcultivation, vineculture, orchards and horticulture additionally are equipped with sensors for leaf wetness.

The datalogger reads the sensors every second, loads the data in a buffer store and computes mean data over 10 minutes, which are spooled in a memory.

The capacity of this memory is big enough for three days. Normally these data are automatically transferred to the PC every day.

By means of a time switch, the PC-program is started every day in the morning between 1 and 3 o'clock. The PC-program carries out the following functions:
- ordering the 10-minutes' average figures recorded in the datalogger and loading them on the PC own hard disc,
- computing one-hour's average figures from the 10-minutes' figures,
- establishing a connection via videotex to the BALIS*-Computer at the Ministry of Agriculture,
- transmissing the one-hour's figures of the past day to the BALIS data base.

The PC-program also contains functions which enable the farmer to evaluate the weather data of his station in the form of graphs, charts and tabulations for a period of his choice.

The transmitted weather data are checked by a plausibility program which regards:
- formal errors
- consistency of time
- limiting figures of climatology
- interior consistency and
- three-dimensional consistency.

* *Bayerisches, Landwirtschaftliches Informations System*
Bavarian Agriculture Information System

The plausible data are available for the models supporting decisions for plant protection. Via videotex everybody can call up the data of each station in average figures per hour or per day for planning plant protection measurements.

COMPUTER SUPPORTED DECISION MODELS

With regard to nitrogen fertilization, simulation models for nitrogen leaching, -release and -uptake are being tested in close co-operation with the Technical University Weihenstephan.

With regard to plant protection, the following models are being developed, tested, or already operated in practice:

Wheat model Bavaria

The wheat model enables integrated plant protection for winter wheat on the basis of both a regular disease survey and the use of epidemiologically orientated control thresholds. The feasibility of this system depends on certain pre-conditions: exact surveys of infestation with regard to the wheat pathogens *Erysiphe graminis*, *Pseudocercosporella herpothrichoides*, *Puccinia recondita*, *Septoria nodorum*, *Septoria tritici* and *Drechslera tritici-repentis*, which are determined with the help of the BAYER-Getreide-Diagnose-System by Verreet/Hoffmann or other optical instruments (Hoff mann et al., 1988).

The concept developed by the Institute of Phytopatho logy of the Technical University of München-Weihen stephan has been testet in extensive exact experi ments since 1988 in close co-operation with the Bavarian State Institute for Soil Cultivation and Plant Production (Bayerische Landesanstalt für Bodenkultur und Pflanzenbau) and the regional Offices of Agriculture and Soil Cultivation (Hoffmann & Verreet, 1991). During 1990, the wheat model was tested for its practicability on 27 farms, during 1991 on 90 farms. The mean frequency of pesticide application was 1.5 in 1990, and 1,4 in 1991.

In parallel to the experimental testing of the wheat model an expert system has been developed by the Technical University of Weihenstephan.

This computer program helps the user to identify wheat pathogens and give explanations to the necessary disease survey. The epidemic development in the field crops recorded by the farmer or the advisory agent in the above mentioned proceedings constitutes the basic information to decide, what kind of fungal disease is to be controlled. The decision support is made by the expert system using the defined threshold values and informations about the fungicides.

The program has been established as a host version and was tested by 20 regional Offices of Agriculture in 1991. At present there are programming activities which will enable BALIS-Videotex to offer this expert system.

Decision support model for barley diseases

The pleasant experiencies with the wheat model gave rise to the development of a decision support model regarding barley diseases, again in close co-opera tion with the Technical University of Weihenstephan. At present, correspondingly to wheat, epidemiological control thresholds for the most important barley diseases are determined and tested in exact experi ments all over Bavaria. Climatic factors are included in the development of this model from the very beginning.

Phytophthora Negative Prognosis

From measurements of temperature, relative humidity and rainfall the space of time after emergence of the potatoes is determined, in which an epidemic of potato blight is not probable. The risk is defined by two critical weather assessment figures. The figure 150 stands for a disease frequency of 0,1% and the figure 270 for 1% disease frequency (Ullrich & Schrödter, 1966).

This negative prognosis program is offered by the German Weather Service in form of map diagrams an via videotex in table form. In Bavaria this is done on the basis of 18 meteorological stations.

The negative prognosis was newly programmed in our Institute an introduced into the BALIS-computer. Each farmer can call up this program by videotex.

From a number of 120 meteorological stations in Bavaria farmers can select via videotex the station nearest to their site. After input of the respective data for the emergence of his potato crops, the farmer will have calculated by the program the individual weather assessment figure. Thus, the farmers can get by dialogue a calculation of the anticipated time free of any infestation risk dependent on the weather for each individual field of potatoes.

Warning service scheme for the control of downy mildew of cucumber
Bedlan (1987), Austrian Plant Protection Office, has compiled all relevant data of downy mildew of cucum ber, such as weather conditions of sporulation, infection, and duration of incubation, to establish a warning service scheme. According to his investiga tions there is a disease risk as soon as two infection cycles have been favoured by the weather situa tion.

In field crops the weather is recorded by small-size meterological stations. We try to establish correlations between the climatic data in the fields and those of our regional meteorological stations. By means of a program, every day the weather data of the stations established in areas of vegetable farming are checked for the possibility of sporulation and infection. Thus, we are enabled to save several inspections in cucumber fields.

Decision support model for the control of pests in winter rape
By this model which is elaborated in the context of a dissertation, the flight of pests into the fields is calculated on the basis of weather data. This knowledge-based decision support model aims at timing the survey and control measures according to the development of the weather situation.

Decision support model for directed control of apple scab
Using two meteorological stations in the Bodensee region, the bases of a decision support model for directed control of apple scab are being elaborated as part of another dissertation.

Before being released for practical use all models are subject to intensive examination in exact experi ments and by selected farmers.

REALIZATION OF THE PROGRAM ENVIRONMENTAL-COMPATIBLE PLANT PRODUCTION

The testing being concluded successfully, the models will be offered for practical use as dialogue programs via videotex. Then, the farmer will have access to the BALIS-computer by the dial-up-network of videotex and call up the desired decision support model. The farmer will have to refer to the agro-meteorological station representative of his area and the computer will order the current weather data delivered by this particular station from the weather data base. Using those data and additionally ordered specific data of the respective crop area, the computer will determine the required pest control measures.

The farmer will be offered this decision support by means of a dialogue program. It is to be noted, that all models mentioned will only offer decision support; the manager of a farm will always have to decide himself on the necessity of implementing pest control measures.

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IRELAND - STATUS OF COMPUTER-BASED ADVISORY SYSTEMS

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ABSTRACT
The use of computer-based advisory systems in Plant Protection is developing slowly in Ireland. It consists mainly of a database and two interactive computer programmes on a videotex system. Its further expansion is limited by the slow uptake of the videotex technology by farmers and by availability of specialists.

INTRODUCTION
Tillage crops in Ireland account for a fairly small percentage of the total agricultural output. Tillage crops including vegetables and fruit use approximately 10% of the utilisable land and account for 12% of agricultural output. The major research effort on tillage crops has been in the area of production research. Research findings are communicated to tillage advisers and hence to farmers. In 1987 an agricultural videotex service Agriline was developed in Ireland. Its primary objective was to develop a viable information and computing system for farmers, agricultural advisers and agribusiness organisations. This videotex service had been on trial for the previous two years.

TECHNICAL ASPECTS
The system is operated on a Vax 11/750 located in Dublin at the headquarters of Teagasc. The software is IVS-100 videotex software supplied by Aregon International. All remote users i.e. all users outside the Greater Dublin area connect to Agriline by EIRPAC, the Irish packet switched data network. Users access the system with personal computers equipped with suitable modems and software or by dedicated minitel terminals.

CONTENT OF AGRILINE

There are two main streams 1) the provision of database information and 2) interactive services. The Plant Protection section of Agriline can be conveniently examined in the framework of these streams.

DATABASE INFORMATION

General information on pest and diseases are dealt with on a crop basis. This database information describes the symptoms caused by each pest or disease and the strategies to be adopted for their prevention and control. It also provides information on the agrochemicals available for the control of the problem including the rate of chemical and the cost of the product. This latter information on availability and price of products is the most used as growers tend to know the symptoms of the various diseases.

INTERACTIVE SERVICES

These can be subdivided into two areas:

(1) Computing services and (2) Clinics

Computing

There are two computing programmes available to users. A cereal herbicide selection programme and a predictive programme for Septoria control.

The herbicide selection programme is outside the immediate scope of this workshop but it is of interest. The user selects from a menu of twenty-six weeds his main problem weeks. He then provides information on the growth stage of the weed and the crop and the relative importance of each weed in the crop. The programme then searches the herbicide database and selects up to five herbicides depending on their efficacy against the target weeds and their price.

The Septoria control programme is a simple menu driven programme which asks the user to respond to questions such as cultivar susceptibility, location and climatic history. It then predicts whether or not a Septoria spray is necessary.

This programme was an early attempt at computer aided decision making and it is too limited to be af much practical significance.

Clinics

There are a number of clinics provided on Agriline, one of which deals with crop problems. The clinic permits a user to describe a particular problem and place the problem on the system. Specialists advisers or researchers respond to the problem usually within twenty-four hours. The problems and their answers are available to all users and the topic is open to discussion by all users after the experts have replied. This service is widely used and it has enabled growers to receive prompt answers to their individual problems.

SPECIALISED USERS

There are a number of closed user groups operating on the Agriline system.

There is a closed user group specifically for the use of the farm advisory service. It also includes a tillage clinic solely for the use of advisers.
An aphid warning service for the prevention of barley yellow dwarf virus in winter cereals is running on this closed user group. Every week from the end of September aphid counts in winter cereal crops are carried out by entomological staff at Oak Park. The results of these counts and the aphid infectivity are entered on the system each week and the adviser can then assess the risk to crops in his area by using t is information.

Oak Park also provides a computer based wheat growth stage prediction service to tillage advisers via Agriline. Advisers input the cultivar, sowing date and geographical location of the crop. A computer programme has been developed in Oak Park by Dr. J.I. Burke to predict cereal growth stages.
This programme uses the information from the adviser and meteorological data from a number of weather stations around the country to predict the date of occurrence of certain key growth stages. These dates are then returned to the adviser via the closed user group.

Currently this service is used mainly for timing of nitrogen, herbicide and growth regulator application. However, it is envisaged that this programme, combined with a yield predictive programme will be used to give disease control advice and cost benefit analysis of fungicide use.

All of the research stations and advisory offices are connected to Agriline. In addition there are approx. 300 commercial growers subscribing to the system. The take-up of the videotex service in its four years of operation is disappointing. However, a large number of users are tillage farmers. Farmers currently can obtain plant protection information from a number of sources other than the official state service. These include technical representatives of chemical companies and co-operative society advisers. This means that there is, in effect, free advice on plant protection available and there is then some reluctance to pay for a service.

There has been difficulties in keeping the databases up to date. The information providers are researchers and specialist tillage advisers whose main priorities are in other areas. Because of this there has been virtually no development of disease model or plant protection systems.

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PLANT PROTECTION BY VIDEOTEX: LIFE AND DEATH

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ABSTRACT
This paper describe a videotex service of plant protection: **AGRITEL**. The main reasons why this service stopped in 1989 were developped.

KEY WORDS: Videotex, Cereals, weed plants.

Since the end of 1983, we have developped a videotex data bank in the Agronomy Faculty of Gembloux. A regional videotex service **AGRITEL** was officially born in 1986 with the collaboration between the Executive Power of the Wallonnia region (French speaking region in the South of Belgium), the private company **COGEMO (SEILLES-BELGIUM)** and a scientific coordination committee which represents mainly Agronomy Faculties and various agricultural organizations **(U.P.A, A.A.B, U.D.E.F.)**. The hardware was a **DIGITAL VAX 11/750**. The videotex standard is **VIEWDATA** (as in Prestel) with the possibility of placing the grammatical accents necessary for the French language. The software is IVS-100 Aregon. In 1988 AGRITEL contained about 2.000 videotex frames on agriculture essentially on cereals (varieties, nitrogen fertilization, phytosanitary protection), market pricelists, legislations (social, fiscal, commercial and juridical), meteorology, technology for the valorization of farm production (animal and vegetable) and gave the possibility for users to communicate via an electronic mailbox. **AGRITEL** also offered two interactive programs: **SIMULI** and **HERBI**. **SIMULI** simulated financial results corresponding to different choices of crop speculations. The interactive program **HERBI** gave the possibility to a farmer to choose the better way to destroy weed plants in fields of cereals **[CLAUSTRIAUX, RAMLOT et CARLETTI, 1988]**. The sequence of videotex frames was constituted by a series of fixed and rolling interactive menus which asked numeric choices: kinds of cereals, kinds of period of growth, kinds of weed plants (one to four simultaneously) and gave the best mixture of active chemicals with efficacity for each plant, the commercial names of these products, their composition in active chemicals and the quantities/hectare. Despite the fact that the Wallonnia Region gives a subsidy of about 500 E.C.U. to buy an add-on microcomputer videotex card or a videotex terminal, and that many demonstrations have been made during two years throughout the country especially with farmers and also in agricultural schools and meetings, there are only some farmers really interested. The subsidy of the region stopped, a request of subsidy to the E.C.C. led to nothing and in 1989 this pilot experience was finished. The mean cost of the production of one videotex frame was about 150 E.C.U. during these years without the cost of the host center (host computer, maintenance,...). The total cost **AGRITEL** has been about one million E.C.U.

These are the main reasons why **AGRITEL** stopped:

- political and administrative blocking-up (especially regional-national conflicts);
- high subsidy for trial experience but too low for a real commercial service;
- no public videotex services with special tarification for communications and hardware;
- no retribution to the suppliers of information (Universities, State agricultural institutions, agricultural organizations);
- 90% of the subsidy to a commercial company (host computer). It was better at the beginning that the host computer was public property if the subsidies were irregular;
- too few interactive programs but the cost is very high. Too few frames with hourly or daily updates but their costs are very high because of the necessity to establish and retibute a structure well adapted for encoding the data.

AGRITEL gave the proof of the good technical possibilities but revealed all the difficulties. Out of France, is videotex a good choice for the farmers? Fax is better than electronic mail; teletext, T.V. and radio is better than videotex for meteorology and general warnings and many interactive programs can run directly on cheap micro-computer without the high cost of communications. But the utilization of these software (except automation software) oblige one to be deeply versed in the knowledge of different matters to introduce good data in a good way and after, be able to interpret the results. It was a basic mistake to introduce computers without first of all offering the farmers adopted training courses and after offering agricultural adviser's support. Otherwise, we will work only with the big farmers (about 5% of farmers), we will only favour them without any social consideration for the others.

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THE DEVELOPMENT OF AN AGRICULTURE PESTICIDES DATABASE AND ITS INTENDED USE WITHIN A NATIONAL CONSULTANCY ORGANISATION

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ABSTRACT
The developement of a computerised pesticide database has presented a major challenge to ADAS, a national agricultural consultancy organisation in the UK. The provision of such a system is an essential part of an array of IT tools to be used by consultants in their work with clients. The development methodologies are described, the problems and solutions to data input and maintenance identified and the intended use of the system is discussed. The resulting user requirements, data model and enquiry specification headings are presented.

KEY WORDS : Pesticide, database, development, computerised, ADAS.

INTRODUCTION
ADAS is at the forefront of research, development and advisory services to farming and other land based industries in the United Kingdom. ADAS has been an integral part of the Ministry of Agriculture, Fisheries and Food but moves are now underway to place ADAS as a seperate executive agency (commencing April 1992) with the eventual aim of full cost recovery. ADAS has been charging for its consultancy services since April 1989 and has achieved an impressive record in the commercial arena and has to date exceeded its revenue targets every year.

One of the key factors in the commercial success of the ADAS business is the successful use of information technology. ADAS developed an Information

Technology Strategy which was approved in 1989. This strategy outlines a portfolio of systems that the organisation requires in order to deliver its services to industry in a cost effective manner and to gain maximum benefit from IT.

In order to implement this strategy, ADAS has an Information Services Unit based in Cheltenham. This Unit provides business analysis, programming, user support, user training, project management and statistical support services. The staff are full time computing professionals some of which have agricultural backgrounds as well as information technology skills.

One of the major projects currently being addressed by this unit is the development of a computerised pesticide database which is to be used by the cropping, horticultural, amenity and environmental consultants in their work for clients. A major business activity for these staff is the provision of advice on best practice of pesticide use.

ADAS first started development work on a computerised database of pesticide information in 1983. The first such system was implemented in a STATUS database and run on a Prince 9950 mini computer at the Ministry of Agriculture's Information Technology Headquarters, Guildford.

This system was made available to ADAS consultants throughout England and Wales via access on the MAFF X.25 network, MAFFnet. Launched in 1985, problems became apparent with the selection of subsets of data. Status proved user-unfriendly and the take up by consultants was poor. The system contained approximately half of the pesticides currently approved for the UK market.

The redevelopment of a computerised pesticide database was identified as a priority within the ADAS IT strategy and work was commenced by the Information Services Unit in March 1990. This work to date is approaching the end of design and moving into the area of prototypes. The purpose of this paper is to highlight the problems encountered, to show the solutions proposed and to illustrate the potential end use of this system in the provision of consultancy services to ADAS clients.

METHODS

The adoption of professional techniques in software development is a vital factor underpinning ADAS commitment to Information Technology. The development of the latest pesticide data base is subject to formal methodologies which cover the following areas.

Project Management
The ISU has developed internal project management and control standards for the development of ADAS software. The standard methodology that this work is based on is Prince (National Computing Centre, 1990), the UK government standard for structured project management. There is particular emphasis on quality management within these standards and these are a vital element of the development process.

Analysis and Design
Analysis and design is carried out using Structured Systems Analysis and Design Methodology (SSADM) version 4 (Central Computer and Telecommunications

Agency, 1990). This paper is not intended to concentrate on the methodology but a brief overview is useful to gain understanding of the development that has been undertaken.

SSADM is modular, each module producing a structured set of end products from a self contained set of projects activities. A typical information system sequence cycle would consist of the following components :

- an IT Strategy Study
- a Feasibility Study (to investigate the system business viability and provide terms of reference)
- a full study (analysis, to produce a specification for the system)
- a development project (to produce a physical design and construct the system)

SSADM covers feasibility through to physical design and its main stages are:

- (Feasibility)
- Requirements Analysis
- Requirements Specification
- Logical System Specification
- Physical Design

SSADM undertakes analysis from three perspectives : functions (a users view of the system processing required to react to events), events (business events such as receipt of pesticide data or system generated events, such as expiry date of label approval trigger) and data (a logical model of the information data, a data flow model and entity-event models).

Used in conjunction with a project management methodology such as Prince it will provide the following end products :

- function and data requirements, defined in detail
- a logical design specifying the operations required to handle the business events, enquiries and the interactions with the user
- a technical environment description, specifying hardware, software and organisational components to implement the system
- a physical design, this includes a data design expressed in terms of specific DBMS data design and a system process design (the description of the process design is taken to a level of detail at which no further design decisions have to be made, other than those which are specific to the physical coding considerations of the language used in implementation).

User involvement
The successful completion of any IT project is dependent on user participation. SSADM and Prince place great emphasis on the participation of users. The development of this pesticide database has been no exception to this. There is in place a user assurance group which works closely with the system analysts on this project.

This user group has been carefully chosen to represent the views of the different consultancy areas within ADAS that have expressed a need for up to date pesticide information. These consultancy areas consist of Agronomy, Horticulture, Entomology, Plant Pathology and Wildlife & Storage Biology.

They meet at regular intervals with the development team to provide the technical pesticide knowledge required for the system to progress and at specified stages to quality review the end products of the SSADM stages. At these quality reviews the development team go through the end products to date, the users discuss and agree (or disagree) the end products and the project proceeds to the next stage or work is undertaken to correct the areas of disagreement. The executive decisions within the project (ie the commitment of resources, approval of project plans) are taken by a senior management board to whom the project manager and user group report. The development of this system represents a successful blending of cropping knowledge, IT skills and a process of users gaining 'ownership' of the system. The development has also involved consultations with the statutory bodies in the

UK responsible for pesticide approvals, the Ministry's Pesticide Registration Division and the Health and Safety Executive. The co-operation of manufacturers providing product labels and manuals has also been greatly appreciated.

RESULTS

The project is still under development and is at present approaching the end of the logical system specifications. The past sixteen months has presented many challenges to the development team and the problems encountered and the solutions provided should prove of interest to other developers.

The user requirement for the computerised database can be summarised as follows :

It must provide the ADAS consultants with comprehensive, up to date pesticide product information for use in their advisory work with the land based industries in England and Wales.

The system must hold all information relating to the use of the product on crops and targets including rates, application details, warnings about use and approval summaries. General information about product handling and storage will not be included. ADAS product evaluations are also to be held by this system.

If a product has been granted an off-label approval for a certain use, this information must also be held by the system.

Information access on this system must be available on line and not involve any knowledge of query languages or report generation, ie it must have a readily accessible user interface including context sensitive help facilities.

The system must have a totally reliable data maintenance infra-structure in order that data may be easily entered, amended, verified by designated authorised personnel.

The system must provide printed output of core enquiries made on a product, a complete product information output, and a tabular printed output of products meeting pre defined criteria. Response times are regarded as crucial, as is concurrency of use. The system has been designed and the technical solution has taken account of the need to provide a sub 2 second response to core enquiries with a total concurrency figure of 150 users.

The security of this system is paramount in all areas but especially data input, amendment, validation and access to ADAS evaluation of products.

An audit trail is an essential requirement in these areas and the system should be controlled by a database manager.

The core enquiries to this system have been specified under the following headings.

MAFFnet enquiries

a) List of Recommendations or Off Label Approvals for a Product
b) Details of a Recommendation or Off Label Approval
c) All details of a Product
d) List of Recommendation and Off Label Approvals for specified Crop, Application timing and up to 5 Targets (of the same Target type) and efficacy sensitivity by Target
e) List of Products containing specified Active Ingredients
f) List of Active ingredients in a Chemical group
g) List of Products for a specified Crop and Product type
h) Tank Mixes and Sequences for a specified Product
i) Changes to a Specified Product

Off line enquiries

a) Product Report (all details for a Product and Recommendations, the user can select the sections they require)
b) Recommendation or Off Label Approval report
c) Summary of Recommendations and Off Label Approvals for a specified Crop or Crop type grouped by Product type (Tabular format)
d) Recommendation Efficacy on Targets for a specified Crop and Product type (Tabular format)

DISCUSSION

Data structure

The most difficult task the development team had to tackle was the design of a data structure (logical data model) that could cope with the complex data relationships found in the different product suppliers guide. Formal data analysis techniques were used (relational data analysis) on a selection of products and other data sources.

The logical data model is presented by Figure 1. Commercial reasons prevent the release of complete entity descriptions and data dictionary definitions.

The most complex products are herbicides although insecticides and fungicides should not be viewed as simple in this context. Over 50 products representing all the pesticide types and differing levels of complexity were studied. The aim was to produce a highly flexible 'ideal' data structure.

ADAS consultants are interested in the specific uses of these products ie a recommendation for at rate of a particular pesticide depending on the crop and targets that require treatment. They are also interested in finding out the alternatives available to them ie how many other products have recommendation for use on the particular crop and targets in question.

Consultants will often want to make product level enquiries ie how many uses (recommendations) does this products have, at what rates can it be used, how many crops and targets does it cover. They will want to know the efficacy of these products against the recommended targets, both the manufacturers opinion and the ADAS evaluation.

The sources used for this study displayed a lack of standardisation in the way that product data is presented by suppliers in the following areas :

a) Determinating Recommendations
A recommendation in this system equates to a rate of product. Rate is defined as 'a single rate or rate band in the manufacturers text'. The use of a rate or rate band will be determined by the manufacturers text and the technical knowledge of the data inputter.

The list of factors used to determine a single recommended rate were different depending on the product. It became necessary to provide a concept of rate determining factors product by product to merge data relationships that represented individual recommendations. In many products a broad rate for a group of crops and associated targets was further subdivided by other rate determining factors such as soil type, soil moisture, application date, growth stages of crop and target, season or climate.

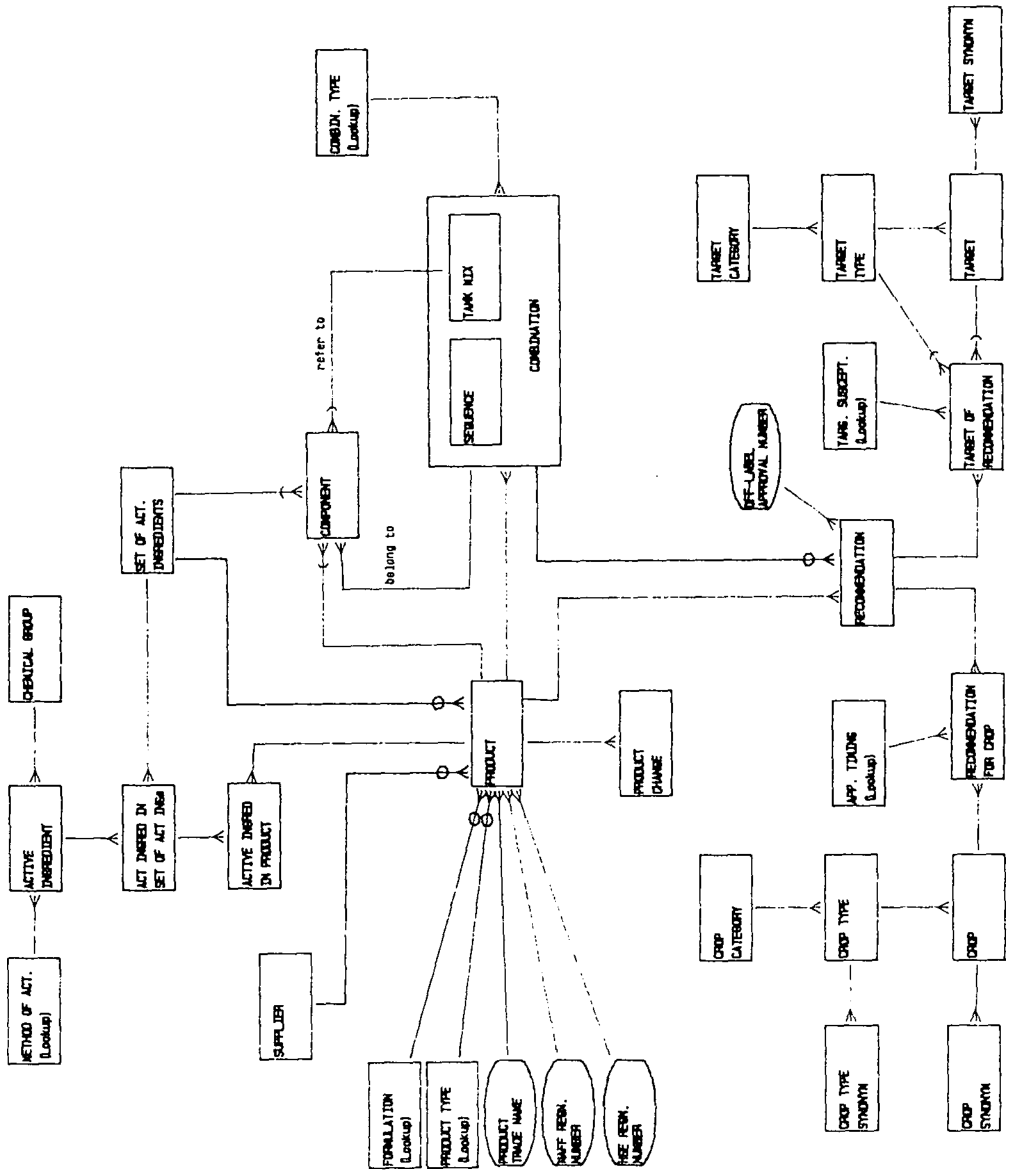

Fig. 1. Logical data model.

The system design encourages rates or rate bands to be entered at the highest logical level but where the inputter decides that a lower level of rate is required this is easily accommodated.

Every entity on the logical data structure was described and every data item defined in a data dictionary. The user involvement here is substantial and the work in defining agreed data item definitions in the areas of standardised crop names, target names, efficacy scores and crop/target synonyms is still on going.

However, the relationship between a product, its recommendations and the associated crops and targets was agreed. In subsequent tests, manually transcribing data into prototype data tables the relationships were shown to hold true (a three month trial of interpretation and input using a mix of technical and clerical staff was undertaken in 1990).

b) Tank Mixes

The area of tank mixes ie the use of one product in combination with other products has proved very complex and difficult to model. In reality a product could also be used in combination with sets of active ingredients as well as other products. It could also be used in sequence with other products and/or combinations of products and/or set of active ingredients.

The development team in conjunction with the users identified two sub types to this Combination Entity, Tank Mix and Sequence.

A tank mix could be either of the following :

Compatible tank mix (CTM) - products or sets of active ingredients that can be safely mixed with the primary product (primary product is the product whose manual or label from which the information is being extracted). CTM's can cover more than one pesticide type (ie herbicides, fungicides and insecticides).

Recommended Tank Mix (RTM) - products or sets of active ingredients which provide a wider area of efficacy than the primary product alone. These tank mixes are defined by recommendations or by label approvals for the primary product. RTM's cover one pesticide type only.

A sequence is defined by a recommendation for a product. It is a set of Products, Active ingredients Groups or tank mixes which are applied in a set order. Sequences are unusual in this context but several herbicides carry such recommendations (eg Avadex, Monsanto Ltd). Sequences cover one pesticide type only. The system will not cover managed pesticide programs in this version but the data structure is flexible enough to allow this at a later date.

c) Product identification
The previous system design relied on the use of MAFF or HSE approval registration numbers (MAFF, HSE, 1991) for identification of a product. Unfortunately this proved to be unreliable as these numbers are not unique to an individual product. There are rare instances of the same product being manufactured or marketed by two different suppliers under the same registration number.

A product is uniquely identified by a combination of the product trade name and associated supplier (manufactured or distributor) name. In this system each product/supplier combination i viewed as a unique product and a system generated number is assigned. MAFF and HSE Registration number attributes of the Product entity. This system will allow the use of these numbers as operational masters ie another point of access to the data group. The ordinary user can thus easily drive an enquiry using a familiar product attribute.

d) Crop and Target Hierarchies
In order to make this system user-friendly, crop and target hierarchies have had to be developed. As mentioned earlier this work is still ongoing. The actual structure and mechanics of the hierarchy have been agreed and the user group are now working on providing an agreed English common name, Latin equivalent(s) and agreed synonyms for crops and targets.

As the data model indicates there is a three level crop hierarchy and a three level target hierarchy. In common with other, 'lookup', tables on the system, users will be able to search for names or synonyms either manually or automatically by entering a name or a partial name using wild card characters. Users will be able to enter at any level of the hierarchy.

e) Approvals
Much interest has been expressed by the ADAS consultants (cropping advisers and horticulturists in particular) in approvals for product use administered by MAFF. Approval information is not readily discernible from product labels or manuals, ie it is not always evident which approvals (or part of an approval) apply to which recommendation within a product.

This system design therefore only details approval comments to record approval information relating to the product and its recommendations. There is an automatic withdrawal of product facility invoked when the approval(s) withdrawal date has been reached.

It is the data managers role to account for part approval revocations and to use the extensive update facilities to alter the product database to reflect these.

ADAS consultants placed particular emphasis on off label approval information about products. Relational data analysis on off label approval documents supplied by MAFF proved that of labels are best handled as recommendations, ie they are approved off label recommendations for the use of a rate or rate band on specified crops and targets. Off label recommendations are identified as such in the data model and also carry an automatic expiry date mechanism as described above.

Data input

Until the input trial was undertaken there was no clear idea of the level of resource required to input the data or the type of inputter (ie level of technical expertise) required. The lack of standardisation in the presentation of product information makes the interpretation and input of data an important task which should be done by technically competent staff. Data input will represent a significant cost in the implementation of this project.

The most successful strategy to introduce standardisation is probably legislation, as such this is outside the scope of this project. The trial demonstrated conclusively that specialist technical staff were required to not only validate the data but also interpret and input the data form the product manuals.

Intended use

The pesticide database will be run on an Amdahl 5990-350. It will be implemented on the relational database INGRES operating in a Unix MAFFnet. This machine will handle all the processing and data storage. It is currently estimated that over 500 megabytes of disk space will be required to accomodate the database.

The consultants will be linked to this system via MAFFnet from their portable or desk top personal computers. MAFFnet access points are available at all ADAS consultancy offices.

The system has been designed to accomodate the needs of all consultants within ADAS who have an interest in pesticides.

The consultants identified as the main user groups are generalist agriculturists, horticulturists, and specialist agronomists, horticulturists entomologists, soil scientists, plant pathologists, wild life and storage biologists.

It is envisaged that most on line enquiries will be made by consultants in direct response to the client.

The off line enquiries are likely to be used by consultants when writing consultancy reports or preparing papers or articles for publication. These enquiries are made on line but are processed and printed off line.

All these enquiries can produce hard copy output to the consultant if he/she so requests.

As a consultary organisation ADAS has to be aware of the potential loss of earnings that can result from litigation. The provision of this pesticide data base should reduce the litigation incidence, however, it will not be used as a litigation defence. All output from this system to the consultant emphasis clearly the need for the client to consult the product label.

Another significant benefit from this system will be the increased efficiency with which ADAS consultants can retrieve pesticide information. The savings in staff costs for these individuals is substantial.

The future

The development of a standardised method of presenting and accessing pesticide information will enable the ADAS consultant to more effectively use pesticide modelling systems. The two types of system have a natural link, the recommended use of a rate of pesticide. The pesticide modelling system in conjunction with the skilled consultant can identify and justify the need for pesticide usage, the pesticide database can then provide the product choices, details and caveats that apply to that usage.

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PESTBASE: A RELATIONAL DATABASE FOR THE EVALUATION OF ALTERNATIVES FOR ENVIRONMENTALLY HARMFUL PESTICIDES

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ABSTRACT
A relational database, PESTBASE, has been developed to facilitate the evaluation and selection of non-chemical and chemical alternatives for environmentally harmful pesticides with respect to the effectiveness for pest control. PESTBASE presently includes data on 93 environmentally harmful pesticides, 253 chemical alternatives, 475 non-chemical alternatives, 637 pests, 457 crops, 3800 applications of environmentally harmful pesticides and 14200 applications of alternative control measures. For 2000 applications of environmentally harmful pesticides alternatives are available ranked according to their effectiveness in pest control (ranking from low to high). The current version of PESTBASE is being expanded and other aspects such as selectivity of alternatives will be included which will provide more complete information regarding the usefulness of possible alternative pest control measures.

KEY WORDS: relational database, PESTBASE, environmentally harmful pesticides, alternative pest control measures, plant protection.

INTRODUCTION
The government of The Netherlands has developed a long term crop protection policy with the goal to reduce pesticide input by at least 50% by the year 2000 (Anonymous, 1991). Based on environmental criteria for leaching into groundwater, soil persistence and toxicity for water organisms 144 chemicals have been indicated as environmentally harmful and their use needs to be restricted. Ninety-five of these chemicals need to be restricted before 1995: 29 herbicides, 25 fungicides, 30 insecticides, 4 insecticides/acaricides, 5 nematicides with herbicidal, insecticidal and fungicidal side-effects and 2 plant growth regulators.

In order to restrict the use of environmentally harmful pesticides, alternatives need to be available for pest control. However, an overview of possible alternatives for different applications of environmentally harmful pesticides was not available in The Netherlands. Because such information is needed for further agricultural policy making, both chemical (i.e. environmentally less harmful) and non-chemical control methods (e.g. biological control agents and cultural practices) were evaluated for their potential as alternative control measures (van de Baan et al, 1991).

The research was divided into two phases. In the first phase, reported here, the availability and efficacy of chemical and non-chemical alternatives for all applications of each chemical to be restricted before 1995 were evaluated. In the second phase of the research additional data will be included for each alternative.

A relational database, PESTBASE, was developed to facilitate the evaluation of possible alternative control measures using a personal computer (IBM or compatible). The flexibility of PESTBASE is such that the database can be easily expanded in depth (adding similar type of data) and in width (adding new type of data). PESTBASE is a useful tool for evaluating a large data set in various ways.

MATERIALS AND METHODS

Input data on the types of applications and use of environmentally harmful pesticides were based on their registration details. Data on both chemical and non-chemical alternatives were obtained from the literature. Various sources were used such as scientific journals, research reports, extension bulletins, documents for plant protection and popular agricultural journals. For the literature search 'on-line' versions of AGRICOLA, CAB, AGRIS and BIOLOGICAL ABSTRACTS were mainly consulted.

For each environmentally harmful pesticide and chemical or non-chemical alternative the following type of data were obtained from the literature:
1. control measure: name of chemical or control method.
2. crop: name of crop for which the control measure can be used.
3. pest: name of pest which can be controlled by the chemical/method.
4. specification: specific data regarding the use of the control measure (e.g. time during the year a chemical can be used; variety of crop that can be treated).
5. effectiveness: effectiveness of the chemical/method to control the pest as mentioned in the literature source.
6. reference: literature source from which data were obtained.
7. judgement: judgement regarding validity of literature source/data.

For the storage and processing of the input data a relational database, PESTBASE, was developed. A special program was developed for data input, thereby guarding the referential integrity of the database. This program can also be used for executing on-line queries on the database. Using a report generator various types of reports can be produced. The relational structure of PESTBASE allows for the evaluation of data in various ways according to the users need. PESTBASE consists of 8 data files at 3 different levels containing the following data (Figure 1):

Level 1

- control measures: name of chemical or control method; type of control measure i.e. environmentally harmful, chemical alternative or non-chemical alternative; identification code.
- sections within agriculture: name of agricultural section (e.g. vegetables, fruit, arable crops); identification code.
- pest groups: name of pest group (e.g. insects, fungi); identification code.
- specifications: specifics regarding control measure (e.g. chemical to be used as a seed treatment, biological control agent commercially available); identification code.
- literature: names of authors and year; title; source; identification code.

Level 2

- crops: name of crop; section within agriculture to which crop belongs; identification code.
- pests: name of pest; pest group to which pest belongs; identification code.

Level 3

- evaluations. For each record in the evaluation file the following data are entered using identification codes:

control measure - crop - pest - specification - effectiveness regarding pest control - literature reference - judgement regarding validity of literature source.

The type of report that can be generated based on the current version of PESTBASE provides information for each enviromentally harmful pesticide regarding the crops and pests for which the pesticide can be legally used together with possible alternatives including specifications regarding their use, their effectiveness for pest control and literature references. Figure 2 gives an example of such information output. However, other types of reports can be generated depending on the type of information the user is interested in. For example one can generate a report on the available non-chemical alternatives for weed control in a particular section within agriculture or on effective chemical alternatives for pest control in a particular crop.

RESULTS AND DISCUSSION

The current version of PESTBASE includes the following input data: 93 environmentally harmful pesticides to be restricted before 1995 in The Netherlands; 475 non-chemical alternatives; 253 chemical alternatives; 457 crops; 637 pests; 328 references. The following data are stored and information is generated by PESTBASE: 18000 evaluation records; 3800 applications of pesticides to be restricted before 1995; 14200 applications of alternatives; 2000 applications of pesticides to be restricted before 1995 for which alternatives are available ranked according to their pest control effectiveness (ranking from low to high).

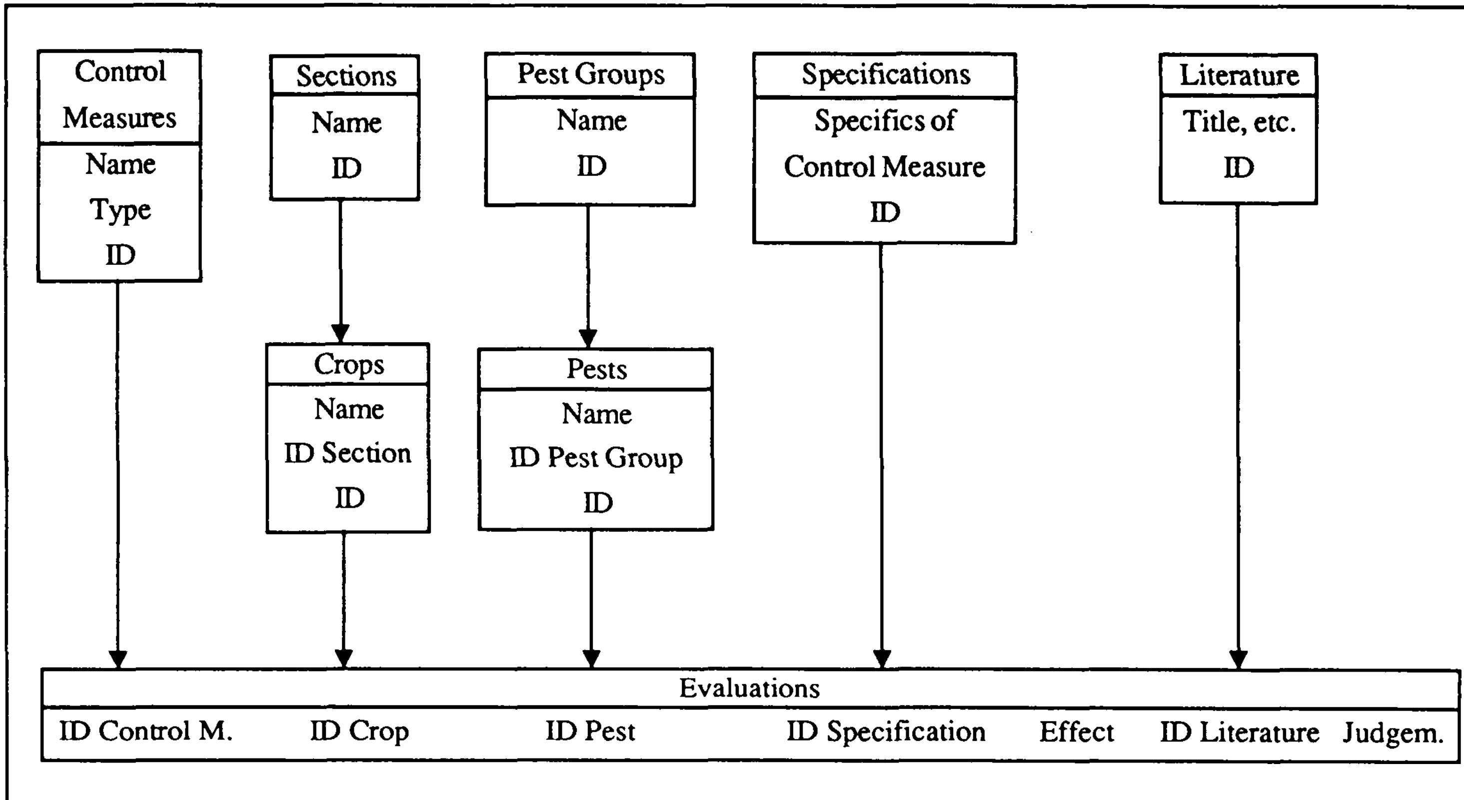

Figure 1. Structure of PESTBASE.

Crop	Pest	Control Measure	Specification	E	Ref	J
AZINPHOSMETHYL						
apple	codling moth (Cydia pomonella)	diflubenzuron	-	3	0011	4
		pheromone (confusion technique)	field trial	2	0129	3

Figure 2. Example of type of report generated by PESTBASE. E = efficacy of control measure ranking from 0 (none) to 3 (good). Ref = literature reference. J = judgement on validity of reference ranking from 0 (unreliable) to 4 (reliable).

The current version of PESTBASE is in the process of being expanded. Besides the efficacy of possible alternatives the following aspects regarding alternatives will be included: selectivity/side-effects on natural enemies; environmental impact; availability for practical use. Based on those data, more complete information regarding the usefulness of possible alternatives will be available, and decisions can be made for restricting the use of environmentally harmful pesticides. An international version of PESTBASE will be developed which may allow for linkage with other computer-based plant protection advisory systems.

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FINLAND - REAL TIME INFORMATION SYSTEM FOR AGRICULTURAL PRODUCTION

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ABSTRACT
A national project for monitoring and predicting field crop production has been started. The aim of the project is to build a system for interpreting weather and cultivation data and pest and disease observations and for predicting crop development, yield, quality of yield and pest and disease risks. The information system is planned to enable direct contact between farmers, advisors and experts. One expert system included is an expert system of cereal leaf diseases. Digitized pictures of diseases are used in help screens.

KEY WORDS: Information system, weather, cultivation, prediction, GIS.

INTRODUCTION
The Finnish national project for monitoring and predicting field crop production has been started in Agricultural Research Centre. The aim of the project is to build a system for interpreting weather and cultivation data and pest and disease observations and for predicting crop development, yield, quality of yield and pest and disease risks. The system management is based on modular expert systems and on GIS. Currently the structure of the expert systems and data handling has been programmed in a pilot system.

The second stage of the project is to make the information system available in real time to advisors, farmers and administrative personnel. The information system is planned to be reachable through the physical net AGROPOLIS/AGRONET. The net enables direct contact between farmers, advisors and experts.

One of the expert systems included in the information sytem is an expert system of cereal leaf diseases. The aims of the expert system are:

- to help farmers and advisors deciding on fungicide use
- to be used as educational program at all levels of agricultural education
- to help researches who give fungicide use recommendations to express complicated decision rules

The expert system is intended to be used independently of other programs or to be coupled to crop development and yield potential prediction models. Estimates of profitability of fungicide use are considered to be conditionally probabilities of yield increase caused by fungicide use given a crop development stage and intensity of leaf diseases. Digitized pictures of diseases are used in help screens which are called by press buttons.

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ELEMENTS OF COMPUTER-BASED PLANT PROTECTION SYSTEMS

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ABSTRACT
Elements of computer-based plant protection systems are described by means of examples taken from plant protection systems for cereal diseases, especially for winter wheat. The essential components required for decision making in the field during a single season are discussed. This comprises the actual state of knowledge implemented in advisory systems as well as desirable facets which should be included in these systems in the future.

KEY WORDS: decision making, disease assessment, disease forecast, disease-loss relationships, disease control

INTRODUCTION
Over the last few years, computer-based plant protection systems have been developed and to some extent put into practical use. In Germany, for instance, several computerized advisory systems for winter wheat are now in the test phase, e.g. EPIPRE (Harmuth & Weng, 1987; Zadoks, 1989), PRO_PLANT (Frahm et al, 1990; Nigge & Volk, 1991), WEIZENMODELL BAYERN (Stephan, 1991) and the approach of Stangl et al (1991). Especially in the former GDR, computer programs to monitor and control individual diseases in winter wheat have been developed, for instance for mildew (Rossberg & Kluge, 1989; Kluge et al, 1989), for eyespot (Rossberg & Groll, 1989; Groll & Gutsche, 1989) and for glume blotch (Rossberg et al, 1989). The level of sophistication and the number of pathogens involved differ widely but the basic elements included in the systems are rather similar. In this paper these components are described by means of examples taken from plant protection systems for cereal diseases, especially for winter wheat. The technical aspects of computer-based systems, for instance hardware configuration, programming language, data transfer etc., will not be discussed. Emphasis will be placed on

the essential elements required for decision making in the field during a single season. This comprises both tactical and operational decisions (Lutze, 1991), i.e. decisions which need to be made only once prior to planting and those which have to be made repeatedly during the season.

TACTICAL DECISIONS

Tactical decisions are medium to short term decisions which are only made once before sowing, for instance using the decision tree of Norton (1976). At this stage the following problems have to be solved:

- determination of the sowing time,
- choice of cultivar,
- treatment of the seed, etc.

The recommendations of a computer-based advisory system stem from a data bank of the available cultivars, their yield potential and disease resistance. Field specific attributes such as high risk of disease occurrence should also be taken into consideration in the choice of cultivar. An example is the model GENIS (Kübler, 1988) which is designed to choose the best winter wheat cultivar for a given field. In any case the cultivar data bank should be regularly updated in order to account for changes in susceptibility of cultivars to diseases and for new cultivars. For the decision on seed treatment as well as on fungicide application later in the season, an actual data bank of permissible fungicides is indispensable.

OPERATIONAL DECISIONS

Operational decisions are short term decisions which have to be made repeatedly during the vegetation period. In the context of this paper these decisions refer mainly to the following problems:

- necessity of fungicide application,
- choice of fungicide,
- amount of fungicide,
- time of application.

The essential components for decision making during the season are: the prediction of the future state of diseases in the crop based on the current state and its recent behaviour, the degree of loss to be expected when no control measures are undertaken, the effects of control measures on the future state of diseases and yield loss, and the economics of control based on expected yield and attainable price.

Determination of the current disease state in the field

Control decisions are primarily based on the situation in a given field, i.e. on the composition of the detected diseases and on the level of the different pathogens. The first problem which presents itself is obtaining the correct disease diagnosis. Since the appropriate course of action is highly dependent on the disease state it has to be determined as accurately as possible. This should be achieved with a minimal cost of time and resources. Suitable sampling plans which include definition of sampling units, sampling path and number of samples to be taken should therefore form part of the advisory system. The sampling path need not be fixed but the system should at least provide recommendations, for instance a line transect along a disease gradient, based on information from the last sample. Computer supported sampling plans such as Field Runner (Delp et al, 1986) can facilitate the assessment of diseases in the field.

Disease diagnosis

The correct diagnosis of disease symptoms on the sampling units is a prerequisite for decisions on further control measures. Some diseases can be identified without any problems while with other diseases the 'ad hoc' diagnosis may be difficult or even impossible. For lesions on wheat leaves a diagnostic instrument was developed (Hoffmann et al, 1988) which can be used to discern some diseases, for instance *Septoria nodorum* and *Septoria tritici* by means of their pycnidia. It is an open question wether this level of sophistication is required or if it is in fact acceptable to farmers.

For some diseases, special biological tests are needed to identify a pathogen, for instance the Klewitz-Käsbohrer-test (Käsbohrer et al, 1988) for the diagnosis of *Pseudocercosporella herpotrichoides*. Although farmers are unable to conduct such tests on individual fields, they can be performed on a regional basis by the plant protection service. It is, however, possible to incorporate mathematical models in the advisory system to estimate the risk of the appearance of a fungus based on meteorological data, such as in the model of Stephan (1991) for eyespot (Frahm & Knapp, 1986).

Generally speaking, problems concerning disease diagnosis can be solved by means of computer programs, so-called expert systems which have been developed for disease diagnosis of several host plants, e.g. soybeans (Michalski et al, 1983), apples (Kemp et al, 1989) and muskmelons (Latin et al, 1990). The development, implementation, and adoption of expert systems in plant pathology have been recently described by Travis & Latin (1991). It would be helpful if the essential parts of these specific diagnosis programs were included in a decision support system enabling a user to request a graphical display of typical symptoms as well as a written description.

Disease assessment
In addition to diagnosis, the amount of each single disease per sampling unit has to be determined based on visible disease symptoms. Usually mean disease severity per plant or per certain plant organs, e.g. the upper three leaves, is used as a measure of total disease. Unfortunately disease severity cannot be measured directly and is instead based on estimates and is therefore highly dependent on the ability and experience of the individual scorer (Hau et al, 1989).

One possibility to overcome this difficulty is to train people by means of standard diagrams or leaf models. Recently, computer programs have been designed especially for training in disease assessment, for instance DISTRAIN (Tommerlin & Howell, 1988) or ESTIMATE (Weber, 1990b). It is desirable that certain features of these training programs, e.g. graphical displays of the relevant plant organs affected by a disease at several intensities, should be available in an advisory system in order to help improve the users' disease assessments.

The second approach to obtain reliable estimates is to measure disease incidence rather than disease severity. This means that instead of an error prone estimation, the disease is determined by simply counting the number of diseased sampling units. Severity can then be calculated using an incidence-severity relationship (Analytis & Kranz, 1972; Seem, 1984). This simple procedure has been adopted in the advisory system EPIPRE (Harmuth & Weng, 1987) in which the farmer reports the number of diseased wheat leaves out of 120 leaves and the system calculates the disease severity.

Forecasting the further disease progression
In most systems, a prognosis of the further development of diseases is needed, for instance one week in advance, on the basis of the actual state. Predicted disease levels are compared with predefined thresholds to decide on the necessity of fungicide application. The prediction within the computerized

system can be based on simple empirical rules or on the weather forecast in connection with complex simulation models.

The empirical rules are based on the assumption that a disease increases exponentially with a constant infection rate which is calculated as the mean value determined over a wide range of field conditions. This average infection rate can be changed to reflect important field specific variables already stored in the computer, such as the cultivar, kind of soil and the preceding crop. This approach for disease prediction is utilized in EPIPRE (Zadoks, 1989).

Better disease prediction can be achieved with simulation models where they are available. In the first step the simulator is used to describe the disease progress up to the present time based on the measured weather parameters. This can provide information about latent infections which have taken place but are not included in the assessment of visible disease of the field. The simulated disease severity will usually differ from the severity estimated in the field. Therefore, in the simulation model a procedure is necessary to adjust the amount of disease, including its different categories, i.e. latent, infectious and removed, before it can be applied to predict the development in the future, as in the mildew model ERYPROG (Kluge et al, 1989). Thus simulation does not eliminate the need for disease assessment. If a reliable weather forecast is at hand a simulation model can be used to predict the further development of a disease. Naturally, the weather forecast cannot be as accurate as one would wish, but in any case the use of such unreliable information is better than no information.

For the application of simulation models, actual and past weather data are needed which have to be stored in the computer. As it is unrealistic to demand that each farmer should have his own weather recording device, the data have to be obtained from the nearest weather station. This could be a station of the meteorological service or a special agrarmeteorological station which have been installed during the past few years, for instance 100 stations in Bavaria (Haimerl, 1990) and 17 stations in Rhineland-Palatinate (Zollfrank, 1991).

As with the empirical rules, field specific characteristics, for example plant density, amount of fertilizer applied or the topography, have to be taken into consideration in simulating further disease progression. This can be achieved by defining relative factors for the correction of the development rates based solely on weather. For instance, in the program ERYPROG (Kluge et al, 1989) the factor for the influence of plant density in wheat is 0.9 for a density of 200 to 300 plants per m2 and 1.1 for 300 to 400 plants. Concerning cultivars it may be possible to assign specific parameters to each cultivar, for instance based on tables of disease susceptibility as the "Beschreibende Sortenliste" in Germany. It may, however, be possible to group cultivars into classes according to susceptibility as with the three to five classes used for the prediction of mildew in ERYPROG (Kluge et al, 1989).

Disease simulators have an additional advantage in that they can be used to predict not only a single value of the disease based on the actual weather forecast, but also a probability distribution of possible values. The simulator can be run with several stored sets of usable weather data, for instance weather data which have been recorded in previous years over a similar season period. This will lead to a frequency distribution of predicted disease severity values (Hau, 1988) which can then be used to identify the probability with which the current weather conditions will cause the disease to exceed a known threshold (Hau et al, 1981).

In the field, several interacting diseases can occur simultaneously as it has been reported in winter wheat by Bonfig-Picard & Kranz (1984) and Jörg (1987). In the experiments of Jörg (1987), for instance, five to eight pathogens or pests always occurred on a single plant. Different kinds of disease interaction are possible, e.g. competition, biopredisposition, etc. Many investigations deal with these interactions of pathogens on crop plants, for instance on wheat (Forrer et al, 1982; Spadafora et al, 1987; Jörg, 1987). However, this aspect of mutual influences on disease dynamics is not taken into consideration by computer-based advisory systems although it could be easily handled in computer programs, as Weber (1990a) has shown with his models for the interactions between mildew and *Septoria spp.* on wheat. More research is needed to test if the effects of interactions are significant at disease densities found in the field and therefore the necessity for these interactions to be included in computer models.

Disease-loss relationships

Disease-loss relationships are indispensable for the prediction of yield loss. Teng (1987) has described in detail the techniques used in their development. Many relationships have been reported for single diseases or pests, either as single or multiple predictor models. Most disease-loss relationships are based on a critical point or a few critical stages of plant development. However, for effective decision making each relevant growth stage of the plant should be included. Unfortunately, this aspect of disease-loss relationships is often neglected.

The situation is even worse regarding disease-loss relationships for several diseases. Only a few examples dealing with the combined effect of several diseases on yield have been published, for instance by Jörg (1987). More work has to be done in this area in order to develop multiple disease-loss relationships and implement them in computer-based advisory systems.

Effect of control measures

The effects of control measures on the development of epidemics have been analyzed mainly theoretically, e.g. by Berger (1988), but few intensive investigations have been carried out. The two most difficult variables to predict in epidemic progress are the exact rate of disease increase and secondly to determine the period over which fungicide application exerts an influence on the rate (Berger, 1988). Presently, models incorporate empirical results and therefore considerable research is needed on the epidemiological consequences of control measures.

Another problem is the reduced efficacy of fungicides due to fungicide resistance of pathogens. Many mathematical models (Hau & Braun, 1988) have been proposed to describe the buildup of fungicide resistance and to assess possible strategies for its delay, for instance the application of fungicide mixtures or the alternation of fungicides. Advisory systems should contain this information in order to help farmers to apply fungicides such that the risk of fungicide resistance is minimized.

Decision making

The decision on wether or not to apply a fungicide can be based on either simple empirical disease thresholds or on more complicated economical considerations including disease-loss relationships, effect of control and cost-benefit analysis.

Threshold concept

In some models the decision to spray fungicides is based solely on the current disease situation without predicting further disease development or use of cost-benefit analysis. An empirical threshold for the disease is defined which has previously been validated under a wide range of practical conditions. In the system of Stephan (1991), for instance, a fungicide treatment against barley powdery mildew is recommended if the disease incidence of plants in the field is greater than 60%. This threshold is independent of the field specific parameters, such as cultivar or the amount of fertilizer applied, as well as of economical considerations. However, if control economics were to be considered, the threshold should be increased to reflect the recent tendency of decreasing wheat prices and rising prices for fungicides (Nigge & Volk, 1991).

Several diseases occurring simultaneously on one crop plant interact not only in their dynamics but also in their effects on yield loss. A complex of diseases is difficult to handle with respect to decision making. If, for instance, the disease severities of two diseases are below their respective thresholds, no control measure will be recommended although their combined effect on yield could justify a fungicide application. Of course this problem is connected to the choice of the best fungicide out of those which are available in order to control also non-target organisms. In multiple disease situations a fungicide has to be chosen which can control not only the most important fungus but also diseases of less importance. It is therefore desirable that whenever possible broad spectrum fungicides be given preference over specific fungicides when this would provide adequate control. Such decisions can be facilitated through incorporation of a data bank containing all admissible fungicides and their efficacies for each disease. If, for instance, in the system of Stephan (1991) powdery mildew exceeds the threshold level, the mildew fungicide is recommended which has the best side effect on the second most important disease.

Cost-benefit analysis

Disease-loss relationships predict the yield loss to be expected from the actual disease state provided the disease continues to increase in the previous manner. With an estimate of the probable yield and the attainable price of the yield the loss in monetary units can be calculated. The loss could be reduced by means of a fungicide spray but this increases expenditure of the chemical and labour costs. From an economical point of view a fungicide application is only justified if the cost of control is less than the benefit obtained from the loss reduction due to the fungicide treatment (Norton, 1976). For example Kranz & Hau (1981) explained the procedure to determine the economic damage threshold for stem rust in dependence on wheat growth stage. More complicated economic analysis of crop protection measures can be found in Waibel (1986). It must be emphasized that the level at which a control measure should be taken is not constant but can vary from field to field and from year to year.

CONCLUDING REMARKS

At the present time many computer-based plant protection systems are being developed and practically applied. There is no doubt that the use of computers in plant protection will improve decision making (Kranz & Hau, 1982; Kranz 1988). Although the advisory systems are mainly based on empirical results they can still help the advisor or farmer in disease management. However, intensive research in plant pathology has produced results which are only now finding practical use, for instance several computer simulators for plant diseases. It is desirable that the results of this research be applied to practical problems through the improvement of the decision making process. The introduction of more sophisticated mathematical models will not negatively influence users' acceptance provided that there is no corresponding increase in the effort required to reach a decision. Many problems remain in the decision making process which even the current research has been unable to solve. This refers mainly to the interactions of diseases with respect to their dynamics as well as to their combined effect on yield. Much more research on complex disease situations should be conducted in order to obtain a sound basis for better disease management.

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EXPERIENCES WITH THE CEREAL PEST AND DISEASE MANAGEMENT SYSTEM EPIPRE IN THE NETHERLANDS

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ABSTRACT
EPIPRE is a computerised advisory system for supervised control of cereal diseases and pests. Field specific data and disease incidence monitored by farmers are used to forecast epidemics and consequent damage, which are compared to costs of control actions. During the implementation process, the advisory system developed from a one disease system into a multiple disease and pest advisory system. These developments, the participation by farmers and the resulting frequence of sprays are discussed in this paper.

KEY WORDS: EPIPRE, supervised control, cereal diseases

INTRODUCTION
EPIPRE is a computerised advisory system for field specific control of wheat diseases and pests, based on disease monitoring (Zadoks, 1981; Rijsdijk, 1983). It started in 1978 as a system to advise whether a spray against yellow rust (*Puccinia striiformis*) would be profitable or not, and gradually developed into a system which gives the farmer information about costs and benefits of (combined) sprays against eyespot: (*Tapesia yallundae* stat. con. *Pseudocercosporella herpotrichoides*), yellow and brown rusts (*P.striiformis* and *P.recondita*), powdery mildew (*Blumeria graminis = Erysiphe graminis*), Septoria-blotches (Mycosphaerella graminicola and Leptosphaeria nodorum) and aphids (mainly Sitobion avenae and Metopolophium dirhodum).

Disease and pest incidences monitored by farmers, are used to forecast epidemics during the growing season to estimate expected damage. These forecasts are based on an average growth rate of the epidemic, depending on the developmental stage of the crop. This average growth rate is modified by cultivar susceptibility, nitrogen fertilization, yield expectation, use of growth regulators and pesticides and for some diseases by soil type. Calculated costs comprise wheeling damage, costs of labour, machinery and pesticides.

In this paper the rationale of the supervised control system, its performance and the implementation process will be discussed.

HISTORY OF EPIPRE

Supervised control aims to discourage the unnecessary use of pesticides by advising sprays only then when it is profitable for the farmer. The yellow rust epidemics of 1975 and 1977 in the Netherlands, and the introduction of the effective fungicide triadimefon in 1978 highlighted the need for supervised control for which funds became available. The yellow rust epidemiologist F.H. Rijsdijk, supervised by J.C. Zadoks, then computerised decision rules for yellow rust control. By frequent meetings of epidemiologists, farmers and extension officers the advisory system for yellow rust was succesfully implemented. However, at the same time most farmers adopted the newly released yellow rust resistant cultivars, by which forecasts and sprays against yellow rust were redundant (Table 1). The farmers however, had to deal with other diseases than yellow rust and, in addition, also aphids became important in the intensifying wheat cropping systems. Pesticides but not resistant cultivars were available to manage these diseases and aphids. Their epidemics varied considerably from year to year and from field to field (Table 1). Especially this variation stressed the need for supervised control. In some years and some fields a spray is profitable, in other years or in other fields it is a waste. Therefore the aim of the project was broadened to cover all important diseases and pests and of course more people became involved.

Table 1. Prevalence (annual % of fields infected) of important diseases of winter wheat in the Netherlands. Data of circa 100 commercial fields surveyed annually in July 1974-86.

Year	75	76	77	78	79	80	81	82	83	84	85	86
Eyespot	74	60	63	-	87	85	89	74	92	74	80	52
Yellow rust	74	8	58	-	2	1	6	4	1	7	12	4
Brown rust	39	14	73	-	43	39	82	69	92	15	32	26
Powdery mildew	75	82	74	-	47	38	72	48	71	90	88	79
Septoria's	66	21	39	-	98	99	100	100	100	100	100	95

DEVELOPMENT AND STRUCTURE OF THE ADVISORY MODELS

The rust epidemiologists constructed a rather simple decision model (Zadoks, 1988). Farmers inspected on 20 places (diagonal) in their field 0.5 m. rowlength, and counted the total number of leaves with yellow rust. Based on the susceptibility of the cultivar and whether a nitrogen top dressing was applied or not, a Q-value was obtained to assess damage (Table 2). Damage (fraction yield loss) was then assessed as: (EXP(Q*N)-1), in which EXP is the exponential relation, Q the specific Q-value, N the total number of leaves with yellow rust in 10 m row totally. The yield expectation of the farmer and the fraction damage expected, determined the actual expected damage (in kg wheat/ha). Costs of a spray were estimated by the costs of the chemicals, costs of labour and machinery and wheeling damage. To estimate wheeling damage it was assumed that wheeling destroys 0.5m crop per spray boom width for the first time and 1/2 and 1/3 of this amount for the second and third time, respectively. A spray was recommended when more damage than costs were expected. An advise to spray against rust was only given between the development stages flag leaf just visible (DC37) and beginning of anthesis (DC61). If no spray was advised, the farmers were asked for a new observation after ten to twenty days. The timing was determined by the amount of disease present (but not yet harmfull) and the development stage of the crop. In such way Economic Injury Levels for yellow rust control were available which took cultivar susceptibility, development stage of the crop, nitrogen fertilization, costs and yield expectation into account. More or less the same model was used to advise the farmers to control brown rust in 1979 in a part of the country.

Table 2. Q-values used for supervised control of yellow rust in 1978 and 1979.

	Nitrogen top dressing	
Cultivar	No	Yes
Susceptible	.001	.002
Intermediate	.0007	.0014
Resistant	.00035	.0007

During the incorporation of other diseases and aphids in the advisory system, the monitoring procedure and the advisory models became more uniform and rational (Drenth & Stol, 1990), see Table 3.

In the field during sampling, farmers have to inspect 100 tillers on presence or absence of aphids. From a more or less random sample of 40 tillers of their field, the farmer counts (outside the field) the number of leaves infected with yellow rust, brown rust, powdery mildew or blotches and the number of tillers infected by eyespot. As these assessments are made at 'reading distance' errors are mainly caused by differences in symptom recognition. Simple diagnostic clues were advocated. Spores of yellow and brown rust color your fingers yellow and brown, respectively. With a finger nail you can rub a powdery mildew pustule from a leaf. Score a yellow/brown fleck in a green leaf area as leaf blotch.

Table 3. Structure of the advisory models used in EPIPRE.

1. Transformation of the disease and pest incidences monitored
2. Determine the lenght of the forecasting period until early dough
3. Determine expected growth rate and peak stage
4. Forecast epidemic
5. Forecast expected damage
6. Determine expected costs of a spray
7. Determine whether a spray against a combination of diseases and aphids is profitable or not (and select appropriate pesticides)

The disease/pest incidences are then transformed to the % leaf area infected by yellow rust or blotches, the number of leaf rust sori or number of powdery mildew pustules per leaf and the number of aphids per tiller. To perform these transformations the same functional relation (Nachman, 1981) with specific parameter-values has been used. It is stressed here that these transformations have been used because information on epidemics and damage was available in terms of severity and density and not in terms of incidence. Moreover, a direct sampling of severity and density would result in three or more different sampling procedures. Thus the monitoring procedure, presence-absence sampling, is rather simple and yet detailed for all diseases.

The development stage of the crop at monitoring determines the estimated length of the growing period up till early dough (DC83), when yield formation stops. During this period the growth of the diseases are forecasted. An exponential growth of diseases and pests is assumed until early dough (eyespot, brown rust and glume blotch) or another critical stage (yellow rust, powdery mildew, specled leaf blotch and aphids), depending on the disease. The expected relative growth rate depends on the development stage of the crop (a mean growth rate) which is modified by multiplication factors to include the effect of cultivar susceptibillity, nitrogen fertilisation, growth regulators and soil type. In the models it is assumed that pesticide residuals arrests the disease/pest during a certain pesticide-disease specific time, after which growth restarts. For each disease a different set of factors is used (Table 4).

Table 4. Factors used in forecasts.

Disease/Pest	Cultivar	Nitrogen	Soil	Growth regulator
Eyespot	+	-	+	-
Yellow rust	+	+	-	-
Brown rust	+	-	-	-
Powdery mildew	+	+	+	-
Blotches	+	+	+	+
Aphids	-	+	-	-

All advice-models use yield expectation, crop development stage and pesticide residuals.

The thus forecasted epidemic is integrated over the forecasting period to obtain its AUDPC-value to estimate the expected damage. Many field experiments were conducted to get reliable estimates of damage for the different diseases. The assessment of the expected costs, being well defined in the early models is still used. To assess the profitability of a spray, the efficacy of the fungicides is taken into account for some diseases.

A recommendation to spray against a disease/pest is given if the expected damage exceed the expected costs. Other diseases are then also included if their expected damage exceed the cost of the chemical. If none of the diseases is worth spraying, but two ore more are present, the profitability of a combined spray is also evaluated. By this the Economic Injury Levels for control of a disease or pests does not only depend on field specific characteristics (development stage, cultivars, etc.) but also on the presence of other diseases. Moreover, the advise specifies the expected damages for the different diseases and aphids and the calculated costs, by which the farmer gets more insight in the economics of crop protection in a specific wheat field.

PERFORMANCE OF EPIPRE

The economics of the recommendations generated by the EPIPRE system were compared in field experiments to intensive control and control by the (experimental) farm manager. The advise models for rusts, mildew and aphids were reliable, those of Septoria blotches and eyespot had to be adapted (Reinink, 1986). EPIPRE had positive educational but few short-term economical benefits for (experienced) farmers.

This limited participation. The number of fields participating in EPIPRE and the obtained yields are listed in Table 5.

Table 5. Number of wheat fields which participated in EPIPRE and average yield, tonnes/ha (84% dry matter).

Year	Number of fields	Yield
1978	411	7.2
1979	450	6.5
1980	840	6.9
1981	1155	7.4
1982	1069	8.0
1983	1380	7.6
1984	1100	8.6
1985	816	7.7
1986	862	8.7
1987	586	6.8
1988	382	8.0
1989	306	-
1990	*50	-

* EPIPRE was restricted to farmers participating the project "implementation integrated farming".

Obtained yields were above national average. After its introduction in 1978 the participation increased to approximately 1400 fields in 1983 and decreased afterwards. No information is available how frequently EPIPRE has been used by farmers participating in an experimental information retrieval system (VIDEOTEXT). After 1989 the system was made only available to farmers participating in the project 'implementation of integrated farming'. Farmers participated with circa 1.5-2 fields and in 1980 and 1981 circa 40% of the farmers stopped participation each year (Blokker, 1982). The majority stopped because they learned enough (field inspection, symptom recognition, economics) and did not need the system anymore to support decision making (Blokker 1982). About one quarter of the farmers in the Netherlands which have wheat in their crop rotation participated. The occurrence of the wheat diseases and aphids monitored by the participating farmers were also used to prepare fortnightly survey reports which were published in farmers magazines.

The objective of supervised control is to spray only when it is profitable for the farmer. As disease and pest intensity varies considerably from field to field and from year to year, the advises given annually varied accordingly (Table 6).

Table 6. Recommendations given to participants of EPIPRE during 1982-87, in % fields advised to spray against the specified disease.

Year	1982	1983	1984	1985	1986	1987	1988
eyespot	0	6	10	10	7	13	8
yellow rust	0	8	3	2	2	10	18
brown rust	0	18	3	5	6	12	31
powdery mildew	13	63	99	53	36	45	17
blotches	11	37	37	48	38	119	62
aphids	51	31	38	44	33	42	36

N.B. combined advices are counted twice or more.

Data of table 5 cannot be compared directly with the actual frequence of sprays. As residual effects of pesticides are taken into account no recommendation is given when a field is already sprayed. The majority of the farmers did not follow the recommendations exactly, mainly because they sprayed earlier and used different pesticides than recommended (Blokker 1982). Earlier sprayings were mainly due to the medium of communication. Postcards caused a considerable delay and direct advises by telephone were used after 1984. The different use of pesticides is mainly due to the addition of maneb, which was common farmers practice. Despite these differences, farmers (1974-78 monitored and advised by extension service, 1978-84 EPIPRE farmers) sprayed their fields more often against leaf and ear diseases in years when average annual damage, estimated in field experiments, was high (Fig. 1, Daamen 1990). Control against eyespot was accordingly associated with annual eyespot intensity in May (Fig. 2, Daamen & Stol, 1990). Thus, by use of supervised control, calender sprays were not commonly practiced.

IMPLEMENTATION PROCESS

An intensive communication between the farmers and the EPIPRE team was needed to fit the advisory model to the farmers needs. Meetings during winter in the different districs were used to introduce the system and to discuss the objectives. During the field season, in field instructions were held to improve sampling and symptom recognition. During these instructions in the field, actual problems and criticism were revealed. In addition, many EPIPRE fields were visited by the EPIPRE team to survey the occurence of diseases and pests. After the harvest, results and experiences were discussed with the farmers during regional meetings. This intensive communication was a strong incentive for farmers to participate. In addition, the start of EPIPRE coincided with the introduction of new effective fungicides and aphicides, and, wheat production was intensifying. Thus in addition to an educational incentive also an economical incentive was present. For the (research) members of the EPIPRE team, the synergism due to the confrontation of scientific knowledge with farmers practice in the context of information technology and environmental pollution was stimulating. Governmental organisations supported EPIPRE because of the potential of cost reduction of extension and because of environmental issues.

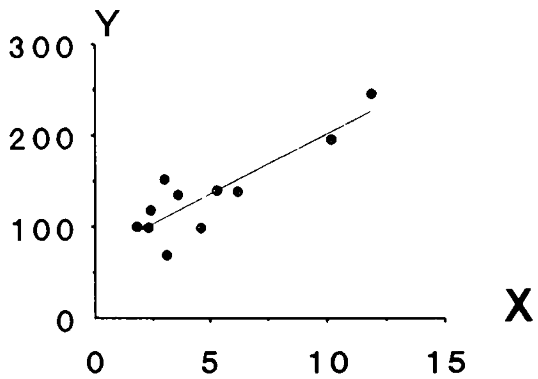

Fig. 1. Estimated annual use of fungicides to control leaf and ear diseases (Y, use in % of fields treated) in relation to an estimate of damage (X, kg/are), being the effect of one fungicide application at flowering on clay soils in cultivar trials (H.Bonthuis and K.Roodenburg, pers. comm.) during 1974-84.

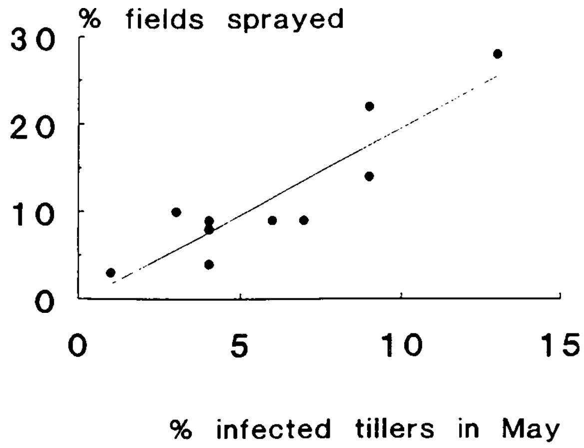

Fig. 2. Annual % of wheat fields treated in May to control eyespot (Y) in relation to annual eyespot intensity in May (X, average % tillers infected, ca 100 survey fields) 1974-84.

FUTURE

Improvements and simplifications are needed (Drenth et al., 1989) For example, farmers like simple and few field observations. The uncertainty associated with smaller samples in monitoring is being evaluated (Rossing et al., in prep). Weather data could be used to assess the need and timing of monitoring. In addition to improvements of sampling, the accuracy of the forecasts and advises do need improvements. Forecasts can be improved considerably by abandoning the use of average growth rates and by using weather dependent growth rates (Daamen & Rabbinge, 1991). In some instances this is not limited by a lack of knowledge. For example, the advises to control eyespot depend on the percentage of infected tillers in May. If weather during spring is taken into account (Fig. 3) forecasts and advises improve. This kind of forecasts is highly appreciated by farmers.

EPIPRE is now not available to farmers in the Netherlands. The advisory model is being incorporated in a general computerised advisory system for cereal cultivation (CERA). Due to this effort, the priority to update, improve and support EPIPRE is low. Moreover, the resources allocated to perform surveys of diseases and pests in cereals were reallocated to enhance the building of CERA.

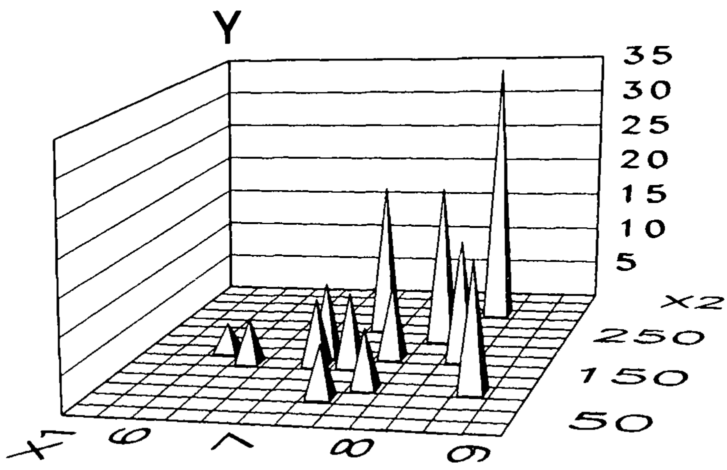

Fig 3. Mean annual incidence of eyespot in July (Y, in % infected culms), in relation to mean temperature in April (X1, oC) and cumulative precipitation in March, April and May (X2, mm). Survey fields, 1974-86.

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EXPERIENCES WITH AND PROSPECTS OF DECISION SUPPORT SYSTEMS IN CEREALS AND POTATOES IN SWITZERLAND

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ABSTRACT

EPIPRE, a Dutch decision support system (DSS) for winterwheat, and HORDEPROG, a similar Swiss DSS for winter barley have been used and evaluated since 1981 and 1985 respectively. Both DSS proved to be reliable in extensive on-farm field trials. Though the mean number of fungicide applications with EPIPRE was 35% lower than with the convential method, there was no difference between the economic return of the two procedures. About 1000 participants make use of our DSS which are avalable on the Swiss VIDEOTEX system. Beside the support of decision making both DSS proved to be highly valuable as tools for the traning of farmers. For late blight control of potatoes, a PC-program named PhytoFAP has been developed recently. It uses weather information, the susceptibility of potato cultivars and the actual disease situation which is monitored by a net-work of appr. 150 observation plots.

KEYWORDS: Cereal diseases, Late blight, EPIPRE, PhytoFAP, Prognosis

INTRODUCTION

Only 15 to 20 years ago the main purpose for the development of risk assessment and forecast methods in arable farming was the identification of critical disease levels or pest situations to prevent yield losses by using pesticides.

Since about 10 years with a high input of chemicals the aim of epidemiological and population dynamic studies turned to estimate wether a pesticide application is really needed or not in order to reduce the massive pesticide use. Therefore, a comprehensive disease or pest forecasting system should estimate the future state of crop diseases or pests, the crop damage and evaluate the situation with a cost benefit analyses. For some few diseases, e.g. late blight (Phytophthora infestans) in potatoes, decision making upon an economic evaluation does not seem to be appropiate since a treatment may be highly needed as soon as the fungus has been detected in a region and the metereological conditions are favourable for infections. The main point of a forecast system for the farmer is to reduce the uncertainty wether to spray or not, respectively a support of his decision.

The following comprehensive, computer based decision support systems (DSS) are used or under development in Switzerland: EPIPRE in wheat, HORDEPROG in barley and PhytoFAP in potato growing.

EPIPRE AND HORDEPROG

Introduction and Layout of EPIPRE

EPIPRE is a computer based DSS for diseases and aphids in winter wheat, developed in the Netherlands (Zadoks, 1981; Rabbinge & Rijsdijk, 1983). In 1981 first tests using the program on the mainframe in Wageningen by on-line connection were performed in Switzerland. In 1983, the FORTRAN program was transferred onto the mainframe of our research station (FAP). At that time the following diseases and pests were integrated in the system:

- eyespot (Pseudocercosporella herpotrichoides)
- stripe rust (Puccinia striiformis)
- leaf rust (Puccinia recondita)
- mildew (Erysiphe graminis)
- glume blotch (Septoria nodorum)
- aphids (Sitobion avenae)

The follow up of EPIPRE's main programs is shown in figure 1. In addition to these programs which are connected to a database, EPIPRE contains data files with disease and pest relevant values (e.g. growth stage [GS] dependent growth rates, prognosis periods etc.) and of data files with susceptibility values for wheat cultivars and pesticides.

The participating farmer has to carry out field observations according to a standardized procedure for the disease and pest monitoring from growth stage 31 to 61 (aphids 59 to 69). Their data are introduced into a computer where a prediction of the future development of diseases and aphids and a corresponding yield loss is calculated. For these predictions basic crop data e.g. variety, yield expectation and exposition of the field as well as other non static agronomic factors e.g input of growth regulators or nitrogen fertilizer are taken into account. The calculated losses are compared with the costs of spraying. Since we assume that most of the treatments have also negative side effects (e.g. resistance, reduction of beneficial insects and microorganisms), in the Swiss EPIPRE system 100.- sFr/ha (= value of 100 kg wheat) are added to the spray costs. Treatments are recommended **only** if the estimated yield benefit is greater than the costs.

1	REGISTRATION OF BASIC DATA (e.g. addres, field exposition, cultivar, yield expectation, techn.equip.)
2	INPUT OF OBSERVATION DATA (date, GS, monitoring data, rainfall,nitrogen, pesticides, growth regul.)
3	CALCULATION OF THE ACTUAL DISEASE SEVERITY (transformation of incidence to severity values)
4	PROGNOSIS OF DISEASES & PESTS (consideration of GS, cultiv., pestic., exposition, nitrogen, gr.regul.)
5	PROGNOSIS OF LOSS EXPECTATION (consideration of yield expectation, prices)
6	BALANCE OF COSTS AND LOSSES (decision making for action: no, single or combined treatment)
7	TIMING OF NEW ACTIONS (timing of application if needed and timing of new field observation)
8	OUTPUT OF RECOMMENDATIONS (incl. summary of former disease observations,applications & fertilization)
-	SUMMARY TABLES FOR DISEASES AND PESTS (tables for actual, general and regional overviews)

Fig.1. **Follow up of core programs of EPIPRE and HORDEPROG**

Until 1984 the leaf rust, the septoria and the aphid modules were substantially modified (DERRON & FORRER, 1989; FORRER, 1989). With new modifications in the leaf rust and mildew modules which led to more observations in critical situations, higher amounts of disease can be tolerated until growth stage 39/45. In this way a quite important part of fungicide applications can be avoided without taking unacceptable risks. Most of these modifications are based on experiences from field trials, but partially also on observations and wishes from the extension service and the participants. Beside a permanent adaptation of the programs a yearly actualization of the cultivar, pesticide and price files is assured.

HORDEPROG

HORDEPROG is a DSS for diseases in winter barley based on the core programs of EPIPRE and was developed at our Research Station (FORRER & AMIET, 1989). HORDEPROG gives spray recommendations for:

- leaf rust (Puccinia hordei)
- mildew (Erysiphe graminis)
- net blotch (Helminthosporium teres)
- leaf blotch (Rhynchosporium secalis)

[- eyespot (Pseudocercosporella herpotrichoides)]

Since 1988 the eyespot module is not more accessible for extern users because eyespot on barley is not of great economic importance. Since then field observations in HORDEPROG are restricted on GS 32 to 51.

Evaluation of EPIPRE and HORDEPROG in the field

Most of the field trials were performed in cooperation with the cantonal or local extension service in farmers' fields in practically all wheat growing regions. These large field trials consisted of 2-3 procedures with 2-3 repetitions. In addition to these trials, EPIPRE was tested together with 5 other treatments in regular small plot trials with 4-5 repetitions (FORRER & AMIET, 1989). From 1981 to 1987 the yield and the economic return (gross return minus application costs) of EPIPRE was compared in 273 field trials to an untreated procedure. Following EPIPRE, the mean yield was 12% and the mean economic result 6% higher. In 224 trials (1982-1987) EPIPRE was compared to conventional spray schemes, too. In this comparison, the mean yield of EPIPRE with 1.0 fungicides on an average was 2% lower than the yield of the conventional procedure with a mean 1.5 fungicide treatments. The economic result was exactly the same with both procedures (FORRER & AMIET, 1989). Because the eyespot and the new septoria module are only active since 1984, these results could be somewhat misleading. A summary of our trials from 1984 to 1990 shows that the result was not changed by this: With a reduction of over 35% of fungicide applications in EPIPRE compared to the conventional spray scheme, the same economic result was obtained (Table 1). As a whole, the results of the evaluation of the field trials proved that EPIPRE recommendations ensure a reliable and nearly optimal disease management. Similar results were obtained in southern Germany where in 42 field trials with 8 different treatments the best economic result was reached with the Swiss version of EPIPRE (HARMUTH & WENG, 1987).

Table 1
Comparison of fungicide use and yield in wheat field trials with treatments according to a conventional (C) spray scheme and EPIPRE (E) in Switzerland 1984-1990

Year	Nb. of trials	Mean nb.of treatments		Yield		Corrected gross return*	
		E	C	E kg/a	C%	E sFr./a	C%
1984	49	0.6	1.4	70.8	102	73.0	99
1985	45	1.2	1.6	68.8	102	68.7	100
1986	35	1.4	1.8	62.8	101	60.8	100
1987	23	1.4	1.8	60.5	101	57.6	99
1988	19	1.6	2.1	71.0	104	68.0	102
1989	4	0.8	2.0	69.9	102	69.4	99
1990	6	0.7	1.5	71.3	101	71.9	99
Ø 84-90	-	1.1	1.75	67.9	102	67.1	100

*Gross return minus costs for product, machinery, labour and secondary costs
E= EPIPRE C= Conventional C%= C in % of EPIPRE

For the evaluation of HORDEPROG, the recommendations of the DSS for winter barley were compared to an untreated and an intensive procedure (Table 2). The results of these trials were almost the same as those for EPIPRE: With a mean of 1.0 fungicide applications in HORDEPROG, a 12% higher yield and a 6% higher economic return than in "untreated" was obtained. Whilst the yield in the intensive procedure with 1.7 treatments was 2% higher on an average, the benefit with this procedure was 2% lower than with HORDEPROG. Unlike EPIPRE our own trials with 5 different procedures revealed that the same benefit as with HORDEPROG can be obtained by one prophylactic application (GS 39) of a fungicide (FORRER & AMIET, 1989).

Organisation of EPIPRE and HORDEPROG

We are responsible for the updating and validation of the programs and the training of extension workers. The training of the farmers in the field is assured by the cantonal plant protection service and by the extension service of the agricultural cooperatives. Until 1986, EPIPRE recommendations were only performed by the mainframe computer at our station. The participants sent their field observations on postcards to the FAP. The same day the data were registered and the computer generated answer letters which were posted immediately. In this way the participant got the EPIPRE recommendation generally two days after his field observation. After 1983 the speed of the post expedition dropped remarkably. In this situation the agricultural cooperatives which were interested in our DSS proposed 1985 to finance a VIDEOTEX version of EPIPRE and HORDEPROG. The VIDEOTEX versions were implemented and tested in 1986 resp. 1987. Since 1988, most of the participants were advised using the VIDEOTEX system (Table 3). Actually very few farmers are directly connected to the VIDEOTEX system.

Table 2
Comparison of fungicide use and yields in barley field trials with no treatment, treatments according to HORDEPROG or to an intensive spray scheme in Switzerland 1985 - 1989

Year	Nb. of tr.	Fungicides (mean nb.)			Yield			Cor. gross return		
		U	H	I	U kg/a	H %	I %	U SFr/a	H %	I %
1985	9	.0	.8	1.4	62.4	109	107	46.1	103	99
1986	13	.0	1.0	1.8	53.4	120	121	40.1	112	109
1987	10	.0	1.1	1.8	55.4	112	116	41.5	106	105
1988	12	.0	1.0	1.7	55.3	111	114	41.5	104	102
1989	4	.0	1.0	2.0	73.9	110	114	55.4	105	105
85-89	-	.0	1.0	1.7	60.1	112	114	45.0	106	104

U = Untreated H = HORDEPROG I = Intensive treatment
% = in % of untreated tr = treatments
cor. gross return = monetary return minus application costs

Generally the extension workers and many cooperatives have a VIDEOTEX terminal at their disposal and farmers contact their extension workers directly or by phone.

Table 3
Number of cereal fields in Switzerland using EPIPRE or HORDEPROG by Mail or Videotex Communication

	EPIPRE			HORDEPROG		
	mail*	Vtx**	Total	mail	Vtx	Total
1981	24	-	24	-	-	-
1982	48	-	48	-	-	-
1983	93	-	93	-	-	-
1984	102	-	102	-	-	-
1985	251	-	251	14	-	14
1986	399	87	486	24	-	24
1987	332	352	684	60	52	112
1988	144	781	925	149	218	367
1989	31	1010	1041	29	210	239
1990	45	978	1023	26	178	204
1991	25	914	939	18	171	189

* mail-system from the Swiss Federal Research Station (FAP)
** Videotex system supported by Swiss agricultural cooperatives in cooperation with FAP

PhytoFAP A DECISION SUPPORT SYSTEM FOR LATE BLIGHT IN POTATOES

In 1989 we started a project for an integrated control of potato late blight (Phytophthora infestans). The main goal of this project is the development and implementation of a DSS that allows to optimize the use of fungicides to control the disease more efficiently with a reduced number of applications. Furthermore, the promotion of less susceptible cultivars is supported and studies are carried out to estimate the influence of the number of primary foci on the disease outbreak.

Evaluation of tools for the decision making

Since the beginning of the project the late blight susceptibility of all 22 officially registered cultivars is tested in 8-10 trials every year. The results of these trials serve not only for information purposes, but also allow us to classify the cultivars in three groups according to their susceptibility.

Out of five tested wheather-based forecast systems, Phytoprog (ULLRICH & SCHROEDTER, 1966) was the most reliable method in own and on-farm field trials from 1989 to 1990 in Switzerland. Nevertheless, in situations with an early and strong epidemic as in 1990, the real start of the epidemic was earlier than the forecasted one. On the other hand the onset of the epidemic tended to be remarkably after the forecasted date in years with a low progression of the Phytoprog curve as in 1991. From these observations, we concluded that the slope of the Phytoprog curve or the weekly Phytoprog value (WBZ) before the threshold of GBZ 150 (GBZ = sum of daily Phytoprog values starting on 1st of May) indicates wether early infections have to be expected or not.

Since the Phytoprog forecast model indicates only the date of the first fungicide treatment, a simple old farmers' rule was tested in our field trials for the application of the following treatments. This rule indicates an application as soon as the rainfall quantity of 10 consecutive days, since the last spray, reaches 30 mm. From our field trials we know that this rule can be misleading, since infections are possible without the 30 mm being fulfilled. Nevertheless, we use this rule in decision making since up to now we couldn't test systems that recognise infection periods.
To get a reliable picture of the actual disease situation, the late blight epidemic is monitored by the cantonal plant protection service, by other extension workers, the chemical industry and many potato growers. In addition to this, a network of about 100 unsprayed potato plots (cv. Bintje, each 3x3m) and more than 40 fields of "biological" or "organic" farms serves for the disease monitoring (GUJER & FORRER, 1991). This network seems primarily suitable to compare the epidemics of different year, but can also be useful for the detection of the onset of the epidemic, especially in years as 1991 with a late start of the epidemic. The high correspondance between the "Bintje" and the "Bio" network (Table 4) indicates that both tools are of great value for epidemiological studies and for a validation of forecast methods. All data of the disease survey were released in a weekly bulletin to inform the extension services and the growers.

Table 4
Results of the "Bintje" and "Bio" late blight network in Switzerland in 1990 & 1991

	1990		1991		Total	
	Bintje	Bio	Bintje	Bio	1990	1991
Nb. of plots	101	39	95	58	140	153
% infected plots	96%	95%	28%	26%	95%	27%
50% of the plots infected on:	June 29th	June 29th	*	*	June 29th	*

Bio = potato fields of biological or organic farms
Bintje = unsprayed Bintje plots of 3 x 3 m
* = 50% level not reached

Layout of PhytoFAP

In 1990 PhytoFAP, a PC-program, was designed. It uses information about the weather, the current disease situation, the susceptibility of the potato cultivars and fungicides. The program demands the input of the name of the cultivar, the WBZ and GBZ values, the rainfall within the last ten days, the distance to the next known field with a late blight attack and the type of the last fungicide that was used in the potato field. By checking a series of rules, the program indicates wether a fungicide application is needed or not (table 5). If an application is recommended, PhytoFAP indicates the appropriate type of the fungicide. If no treatment is advised, it indicates the condition or the date of the next computer session (e.g. "Next session when first late blight attack is known within a distance of 5 km or after a maximum of 7 days.").

In 1991, a year with an extremely late Phytophthora epidemic, PhytoFAP was tested for the first time in 29 on-farm trials. Following the recommendations of the program, farmers applied only 2.8 treatments on an average instead of 5.3 treatments according to their own decision. Though no significant differences in the disease level of the two procedures were registered, we found that our rules were partly too strong. Refinements will therefore be made for the next season.

Table 5
Basic rules for the decision making in PhytoFAP

Susceptibility Group	first treatment	following treatments
High	WBZ > 29 mm or DIST < 10 km or GBZ = 150	RAIN > 29 mm or DIST < 5 km
Medium	DIST < 15 km and RAIN > 29 mm or GBZ > 150 and WBZ > 29	RAIN > 29 mm and DIST < 5 km
Low	DIST < 1 km (late blight within field)	DIST < 1 km (late blight within field)

GBZ = Gesamtbewertungsziffer (sum of the daily Phytoprog values starting on 1st of May)
WBZ = Wochenbewertungsziffer (sum of the daily Phytoprog values of one week; condition is only valuable for WBZ-values between May 20th and GBZ 150)
RAIN = rainfall within the last 10 days
DIST = distance to next field with late blight

DISCUSSION AND OUTLOOK

EPIPRE and HORDEPROG proved to be reliable tools for a reasonable use of fungicides in cereals. Within the last four years about 800 resp. 150 farmers were connected to the EPIPRE and HORDEPROG system. Beside of the use as DSS, both systems are of great value in the training of farmers and extension workers: In Switzerland EPIPRE and HORDEPROG are used as a teaching tool in most of the Swiss agricultural schools.

The limited number of participants of HORDEPROG (table 3) is easily explained: Our field trials showed clearly that one fungicide treatment is needed in most of the cases. Furthermore, with one application in GS 39 the same yields as following HORDEPROG can be reached. Considering this situation, it is quite clear that a farmer is not interested to spend time for monitoring and money for participation (sFr 45.- per field and season). Nevertheless, we assume that HORDEPROG is quite valuable since it helped us and the farmers to recognize an optimized standard procedure.

Though EPIPRE is much more succesfull than HORDEPROG, the number of participants is stable since 1988 (table 3). The main reason for the stagnation could be a lack of time of the extension workers to form and sustain the farmers and the difficulties of farmers and extension workers in the diagnoses of foot and leaf blotch diseases. Since immunodiagnostic kits for septoria diseases and eyespot (UNGER et al.,1990; MITTERMEIER et al.,1990) could be available in near future, we have planned to study the use of such kits within our DSS.

For PhytoFAP, the development of a comprehensive VIDEOTEX version is in evaluation: In addition to the function of the PC-version as a field specific DSS, the VIDEOTEX programs should allow the generation of risk and current disease maps for a regional late blight forecast. In this VIDEOTEX version, the data acquisition (e.g. wheather) must of course be extensively computerized.

For the realization of our plans we consider the leading idea of the Dutch EPIPRE team of about 1980 to be appropriate: " Doing something **for** the farmers implies doing it **with** the farmers" (ZADOKS, 1988).

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PRO_PLANT - A KNOWLEDGE BASED ADVISORY SYSTEM FOR CEREAL DISEASE CONTROL

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ABSTRACT
The task of the computer based advisory system PRO_PLANT is to reduce the input of fungicides, in later stages of all pesticides, to the minimum, which gives essential as good economic returns as high input routine sprays with potential environmental hazards (ground water contamination, pesticides in the air). The system, at first developed for cereal diseases, in a second step till 1994 for all necessary pesticide applications in the main crops, can be used by the farmer as a stand alone version.

The PRO_PLANT system till now consists mainly of disease specific knowledge bases for diagnosis of fungus infections in cereals and rules for optimized fungicide treatments. The knowledge bases are rule-based and derived from expert knowledge and field trials over several years. During a consultation, knowledge from field data, variety resistances, seed treatments and fungicides is considered. Necessary weather data come from the German Weather Service via Btx (or in future ISDN) or from a home-run small weather station. The first prototype has been tested in 1991 with consultants and a few farmers. In 1992 the system will be used by the advisory service in Westfalia and a larger group of farmers, from 1993 on an improved version will be commercially distributed.

KEY WORDS: Knowledge based system, advisory service, cereal diseases, weather data, fungicides

INTRODUCTION

The organisation of advisory work - why PRO_PLANT ?

Advisory work in the FRG is centered at the "Bundesländer" (e.g. Bavaria, Westfalia), which have different organisations. In Westfalia the Institut for Plant Protection, Seed Testing and Apicultural research, a government and farmer aided institution is engaged in applied research and advisory work (for 750.000 ha of arable land with some 500.000 ha of cereals). In order to get a qualitatively better advisory work in different local regions and with the task, to assure realistic yield expectances with a minimum of pesticide input, in 1989 the development of PRO_PLANT was initiated.

This means, that the right ingrediant(s) in the right quantity(ies) should be applied at the right time(s). Better knowledge about infection pressures (from the farmers field or the surroundings) and infection probabilities should allow precise advice on necessary quantities of ingrediants. Improved knowledge on biological principles and pesticide chemistry is necessary too at the farmers desk, e.g. curative potential of fungicides in degree-days, uptake and transport of chemicals in plants a.s.o.(Beresford & Royle, 1988; Frahm & Knapp,1986; Jordan et al, 1986; Shaw & Royle 1986). Above this the farmer has to consider a lot of regulations (ground water protection areas, protection of bees, distances to ponds and rivers), when applying chemicals and planning the management of his crops. In our opinion a knowledge based computer system should help him and the advisory service in fulfilling their jobs (Frahm et al., 1990).

DESCRIPTION OF THE SYSTEM

The system runs on a standart PC (minimum configuration: 640 KB RAM, 20 MB hard disk, VGA/EGA graphic interface, MS-DOS from 3.0 upwards).

Weather data can be delivered to the computer from home run small weather stations or via telecommunications service (Btx) from the German Weather Service. Btx is necessary for comfortable updates and information from the developing group (alteration of the registration of products, changes of resistances in varieties). Especially for handling missing data in weather data Btx is necessary. Since rain data vary on a very small scale, they must be adjusted by the user.

Some characteristics of PRO_PLANT are:

- the system advices spraying applications, if a certain amount of disease has developed and weather conditions have been favourable for further spread, decision and choice of fungicide takes regard of all relevant diseases.

- since application time and choice of fungicide are optimized, the full potential of certain active ingrediants can be used (e.g. flusilazole against Septoria tritici or tebuconazole /cyproconazole against rusts). Therefore the amount of total product can be reduced (Fig.1) or certain sprays can be saved (Volk & Frahm, 1989).

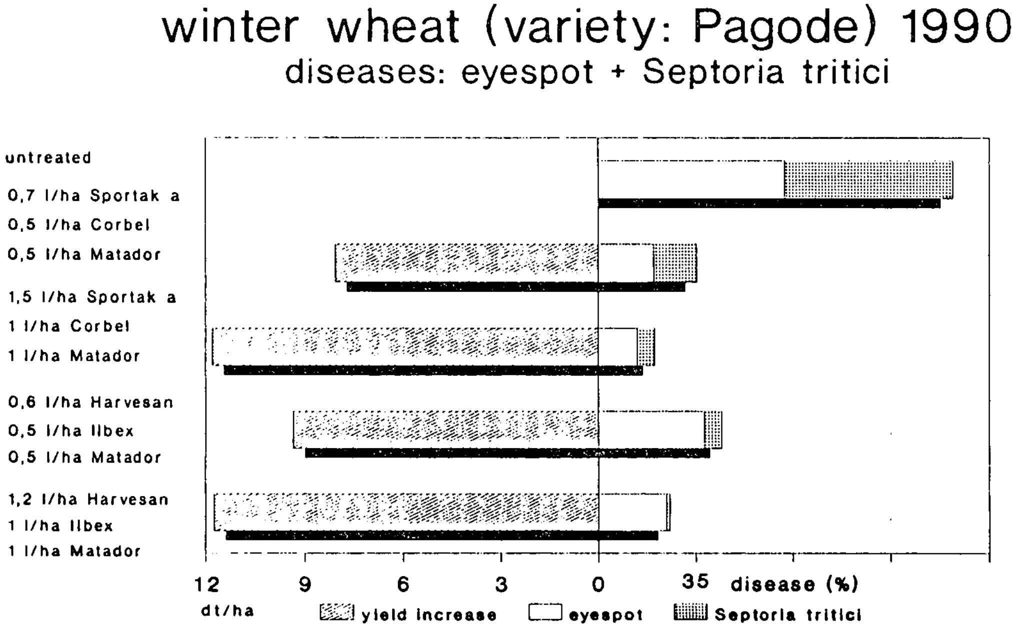

Fig. 1: field trial with half and full amount in comparison

- necessary regulations are strongly considered for each field
- the efficiency of the application is better, if specific characteristics of certain fungicides are taken into account, e.g. temperature and relative humidity (azoles > 10 °C, morpholines < 15 °C and r.h. > 70 %).

A field specific analysis of the economic important cereal diseases and a decision to spray or not for a farmer is called a consultation. During a consultation knowledge from certain data bases is used: field, weather, fungicides, varieties and seed treatments (Fig.2).

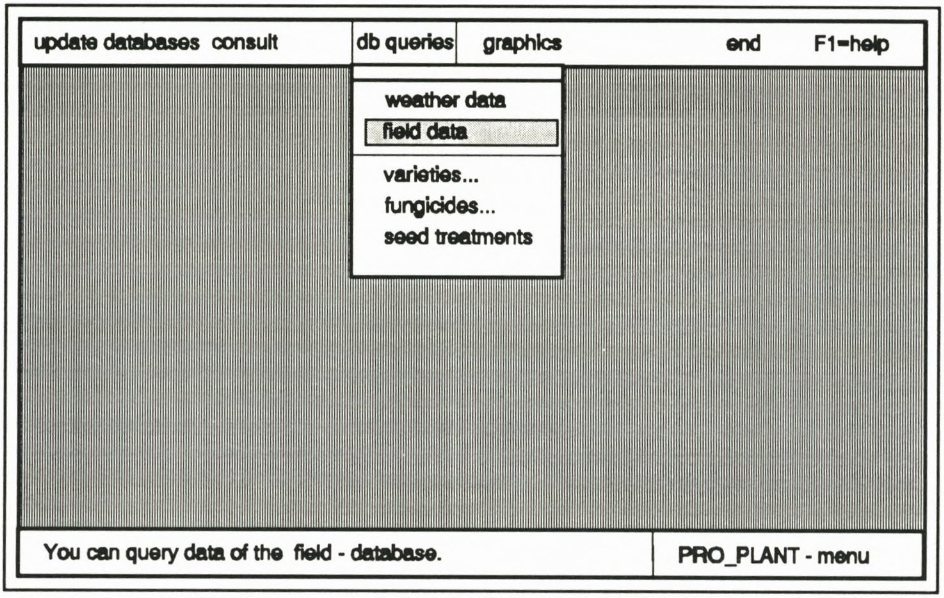

Fig.2: Main menu of PRO_PLANT

A consultation begins with the choice of a certain field. To the farmer information is supplied, whether it would be usefull to consult certain fields. After a field has been chosen (Fig.3), a growth stage of the crop is suggested by the system, which the farmer can accept or change, if he has better information. A graphic-aided help-system can be called up for every step. Generally speaking, the expert system gives answers to every step, when pressing a certain key (normally F1).

Since a lot of fungicides or mixtures of fungicides with liquid fertilizers can only be used, if the plant has a wax layer (the problem of phytotoxicity), the weather of the last few days is analysed, whether a wax layer exists or not.

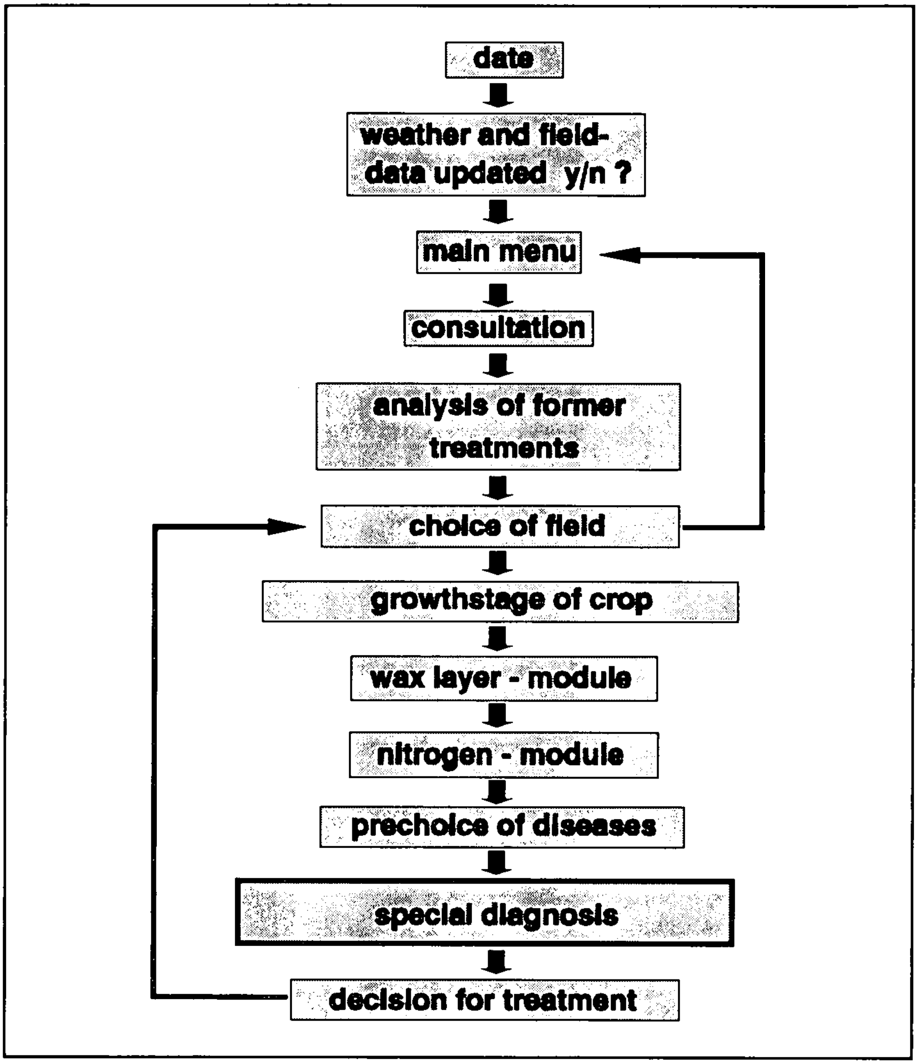

Fig.3: Consultation process of PRO_PLANT

Questions about the nitrogen status of the crop must be answered too, since plenty of nitrogen promotes a lot of diseases e.g. mildews, rusts and net blotch. With regard to these questions, hints are given to rightly guess soil mineralisation, availability of nitrogen from organic manure or fertilizer dressings.

In the so called general diagnosis those diseases are chosen, which have to be evaluated in a further step. For these diseases more information (visible amount of disease, latent infections calculated from weather data) is worked up. The information is integrated in a specific modul (treatment modul). As far as a treatment is considered necessary, those fungicides are chosen, which fulfill all requirements with respect to efficacy and boundary conditions (groundwater protection areas, distance to ponds and rivers, bee keeping areas, wax layer).

These considerations are especially right till growth stage EC 37, because new leaves emerge in a continuos way and the new growth after a spray is always unprotected. From EC 39, when all leaves have emerged, one should be very carefull and use weather forecast too. In certain years with heavy rain in June (1980, 81, 85, 90) applications may not be possible for 10 or more days with extremely favourable conditions for Septoria diseases. With protectant fungicides or less systemic compounds e.g. tebuconazole in EC 39-55 longlasting effects against fungi on the upper leaves and ear often give good economic returns.

At the end of a consultation, a list with possible fungicides is shown with their respective prizes. Information is given, whether a spray can be delayed, when using a special fungicide. The farmer then can choose a fungicide or a mixture, in most cases one he has already at hand.

This information is written into a file and can be used in later consultations. Last but not least he gets an advice at which time the next consultation for this field is necessary.

In a special version of the programm for consultants infection probabilities are calculated from weather data and shown graphically (Fig.4). In connection with an observed amount of disease, a treatment modul derives useful applications. For teaching this part of the programm is very useful.

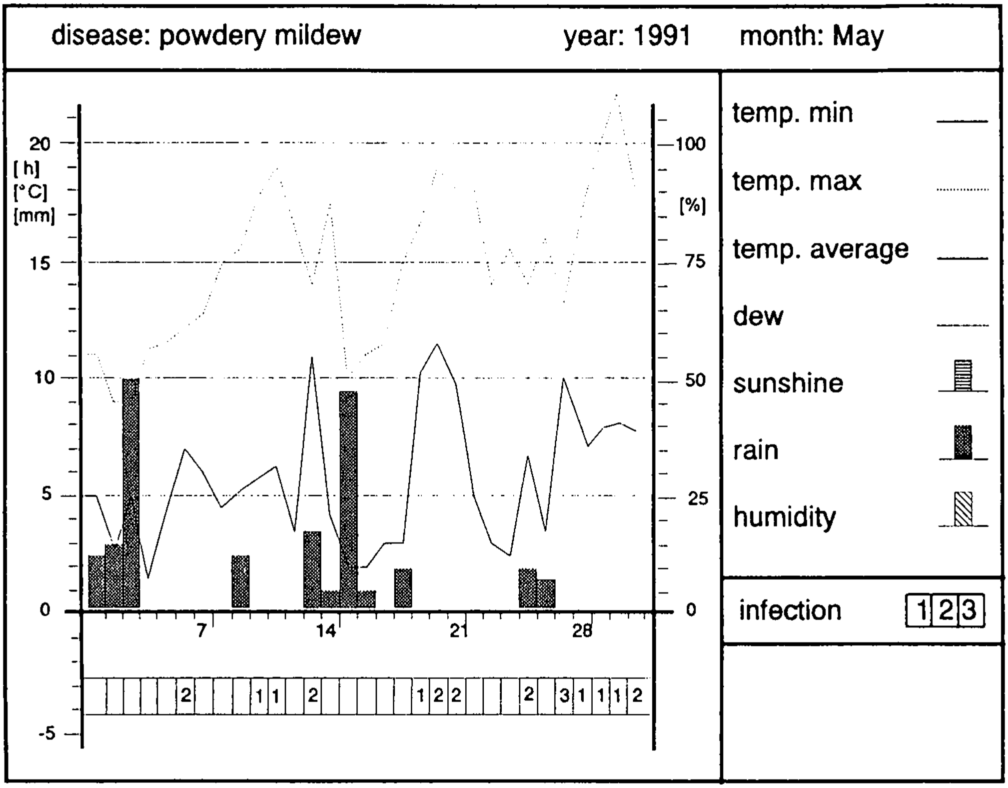

Fig.4: Infection propabilities (see line below the weather graphic) as calculated from daily weather data for powdery mildew of wheat in May 1991.

1 = there is a distinct probability
2 = a higher probability, being worthwhile a treatment or an inspection of the crop after some time, if there is still no visible disease
3 = very high probability, a curative treatment with a well chosen fungicide a few days after this event give excellent control (see May 27th)

FIRST PRACTICAL EXPERIENCES

Trials in 1991 have shown that the system works (Fig.5). Further testing is necessary, because the disease pressure was very low and some diseases did only occur very late in the season.

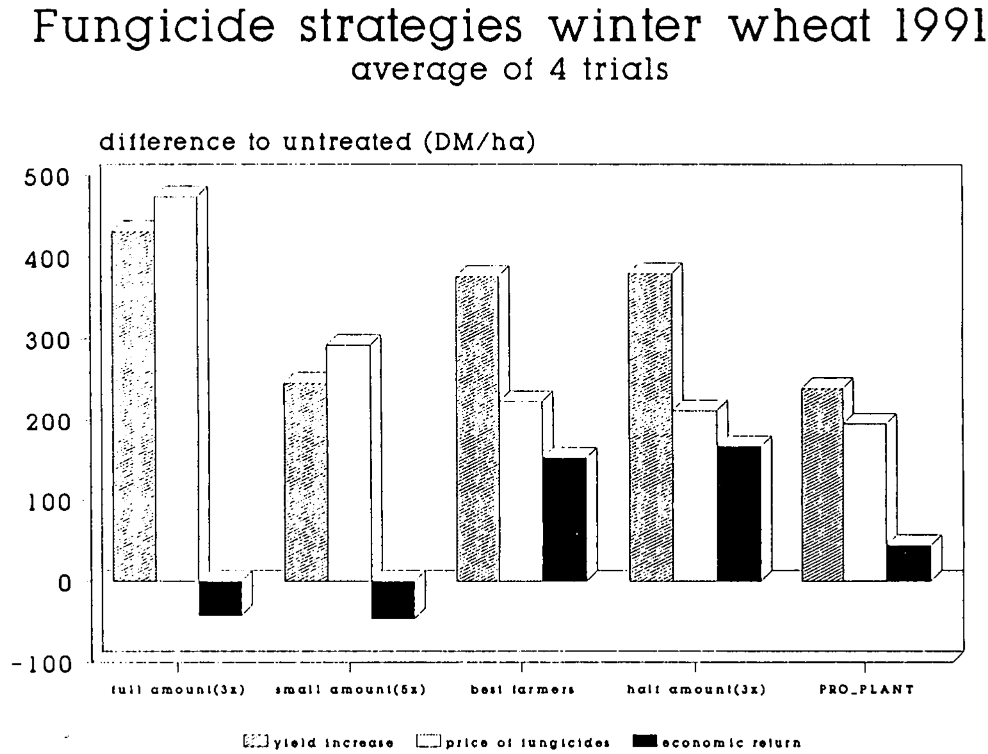

Fig. 5: Different fungicide strategies in comparison

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PERFORMANCE OF 'NORPRE' CEREAL WARNING SYSTEM

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ABSTRACT
A system for prediction of fungal diseases and insect pests has been under development at the Norwegian Plant Protection Institute since 1982. To further the development of an efficient and reliable warning system, a user survey was performed in 1990 to monitor the growers' and advisers' opinion of the present system. 233 of 320 growers/observers and 32 of 51 advisers contributed to the survey by answering one or more questions. 192 growers felt that they had received clear advice through NORPRE. In spite of this only 105 of the reporters had followed the advice given completely. Many of the reporters wanted more field excursions during the growing season with identification of fungi and pests as the main subject of the excursion. The extension units which succeeded technically found that they could retrieve weather forecasts and useful information on plant pathology from the NORPRE host computer.

KEY WORDS: Warning system, Wheat, Barley, Survey, User response.

INTRODUCTION
A system for prediction of fungal diseases and insect pests on barley and wheat (NORPRE) has been under development at the Norwegian Plant Protection Institute since 1982 (Magnus et al 1991).

In 1990, 320 growers in 7 counties took part in the project as observers. In 1991 the number of observers was increased to 535 growers from 15 counties. The participating growers monitor attacks by fungi and pests in one or more of their fields according to a predesigned system. The results of this monitoring are sent to the central warning unit at the Plant Protection Institute, where, on the basis of this information, advice on treatment/nontreatment of the particular fields is given and regional surveies are developed. All surveys and advice given are available to the extension service.

Important premises for practical warning are:

- observations or models that predict the development of diseases and pests
- accessibility to the user
- growers' and advisers' confidence in the predictions

To further the development of an efficient and reliable warning system, we have performed a user survey in 1990 and 1991 to monitor the growers' and advisers' opinion of the present system. This paper will present only the results from the 1990 survey, as the figures from the 91 survey are not yet available.

MATERIALS AND METHODS

The user survey for 1990 was divided into two separate parts, one for the growers/observers and one for the extension service (advisers). Both groups answered a questionnaire, but the sets of questions were different for the two groups. The growers'/observers' questionnaire asked for the growers' name/number, home county and species of cereals monitored. They were asked about their motive for participating in the NORPRE warning system and given three alternative answers:

1. a wish to reduce the use of pesticides
2. a wish to maximize economical output in their production
3. a wish to increase their knowledge of plant protection in cereals

The observers were asked to indicate the relative importance of these three reasons for participation by giving each answer any figure from 0 to 10, 10 being the highest character.

They were further asked to give their opinion of time of issue, quantity and quality of written information concerning their part in the project, as well as of timing, content and duration of field instructions and quality of the instructions regarding monitoring.

The next group of questions was aimed at monitoring the time elasped from when the grower sent his observations and samples till he received treatment advice or predictions by mail. The growers were also asked to what extent they used the NORPRE telephone service.

The growers were further asked whether they had found the advice clear or not, whether they had followed the advice completely, in part or not at all, and whether, in their opinion, the answers given by NORPRE contained important and correct information. They were further asked about what information they missed and what they thought about the advice they had received.

In a paragraph on the use of weather forecasts via NORPRE, the observers were asked whether they considered a 5-day forecast useful, even though the quality of the forecast decreased with time from its release, and whether they wanted a 5-day forecast together with the plant protection advice.

We wanted to know how widespread knowledge and use of computers were among the participating growers and asked whether they had a computer already, whether they wanted to have one, or whether the acquisition of a computer was unrealistic. In this context they were further asked whether they would consider using a computer to retrieve plant protection advice, weather forecasts or other routines from a central database.

The questionnaire ended up by asking whether the observer wanted to continue to take part in the project in 1991 and by opening for the growers personal views and comments.

The extension service questionnaire was to be filled in with the name of the advisory branch and the county.

In this part of the survey we asked those advisers who had admission to the NORPRE database what kinds of data equipment they possessed, and we asked for the type codes of their computer and monitor, diskette size and type of modem used.

We wanted an appraisal of NORPRE's function in 1990 and asked the advisers whether they felt that the information on plant protection they received during the warning season was useful and whether the computer programs they received functioned properly. We asked further whether they found the weather forecasts via NORPRE useful and whether forecast retrieval programs had functioned as they should.

We wanted to know whether the data connection to the advisers were functioning well. We asked whether they transferred the files to their own computers for later use or operated the programs directly towards the NORPRE host computer and how often they used the NORPRE computer programs.

At the end of the questionnaire the advisers were asked to give their own views and comments about their experience with the project.

RESULTS

233 of 320 growers/observers and 32 out of 51 advisers contributed to the survey by answering one or more questions.

The three preformed answers regarding motivation for participation in the project received nearly equal response, with a slight majority choosing best production economy. Most growers found April the right time for distribution of written information and other material. A great majority found the amount of information suitable and the quality good.

137 growers found the time chosen for the field instruction (the three leaf stage) to be suitable. Most participants found the content of field instruction was good and none found it directly bad. 187 growers found a duration of two hours was suitable for the field instruction, and most found the education for the observation work to be sufficient. For 122 observers the time elapsed from sending the observations till receipt of the answers was typically two days. For as many as 73 reporting observers this answer time exceeded two days. Few of the reporters used the NORPRE telephone service to reduce the "answer time".

192 growers felt that they had received clear advice through NORPRE, whereas 13 found the advice given was unclear. In spite of this, only 105 of the reporters had followed the advice given completely, whereas 93 had partly followed the advice. 207 answered yes and only 4 no to the question about whether the answer from NORPRE had given important and correct information. 174 growers consider a 5-day weather forecast useful, even if the quality decreases with time from issue, and 165 of the growers wanted such forecasts together with plant protection advice.

65 out of 233 reporting growers had already acquired a computer and 40 wanted to do so, whereas 102 had no intention of buying one. 75 growers

wanted to use a computer for retrieval of plant protection and weather forecasts, whereas 71 wanted to use the computer to retrieve other routines from a central database.

178 answered yes and 32 no to whether they wanted to continue their participation in the project i 1991.

The paragraph reserved for individual opinions and comments regarding the project brought up several topics. Many of the reporters wanted more field excursions during the growing season. They wanted the number of participants at each excursion to be restricted to a maximum of 20, and that identification of fungi and pests should be the main subject of the excursions.

Even though most of the reporters found the advice received both clear and correct, they would have appreciated an estimate of expected yield losses caused by diseases and pests in their field. Several reporters wanted more information on the models the advice is based on and on the basis for the models in use.

32 advisers answered the extension service questionnaire. Twenty of these felt that they received useful information on plant protection during the season. Eight advisers answered no to this question. Only 12 out of 32 meant that the computer programs had functioned properly. 23 had received useful weather forecasts during the growing season. 6 of the reporters answered no to this question. 20 were satisfied and 6 were not with the computer program for the weather forecasts. As for the data connection to the NORPRE host computer, the corresponding numbers for satisfied/not satisfied were 13 and 9.

To the question about how the computer programs were used, 14 answered that they transferred files to their own computer for later use. 12 of the reporters operated the programs directly towards the NORPRE host computer. 6 advisers used the computer program in the NORPRE host computer daily, 11 used it every week and 2 used it only infrequently. 7 used the programs every day in the appropriate part of the season and weekly the rest of the season. 2 of the reporters used the programs daily in the growing season and infrequently during the rest of the year.

DISCUSSION

This survey has shown that the desire to reduce the use of pesticides in agriculture and to increase personal competence in cereal plant protection are almost as important to growers as the economical aspect of cereal production as incitements to participate in the NORPRE disease and pest warning project.

Most growers find the instructions for the monitoring work sufficient, but some feel the education in identification of disease and pest organisms is insufficient. The reason for this result is that the field instructions are timed to give the observers necessary information before they start their monitoring, which is, of cause, to be done before the diseases and pests have started to develop in the fields.

The time delay from the grower sends his observations/samples till he receives the answer (advice/prediction) has usually been 2 days or more. This lapse of time can be reduced by the use of a telephone answering machine or telefax. Very few had used the answering machine in the 1990 season. A prerequisite for using this device and/or a telefax is that the user is confident in his identification of the disease or pest in question.

Most growers felt that the advice received was clear. Only a few found it unclear. Approximately half of the growers had acted according to the advice given and about 40% of them had done so in part. The growers do not have full confidence in our preliminary set of threshold values and will not always take the risk of awaiting the NORPRE advice for treatment. In parts of the country there is no tradition for the use of pesticides in cereals and growers in these areas may hesitate to apply pesticides, even if treatment is calculated to give profit. Almost all observers found that the received answers gave correct information. This view was further consolidated as the actual yields became known or could be compared with the NORPRE calculations (Magnus & Munthe 1991).

Many of the growers have realized the importance of meteorology in combination with pathology and want a 5-day weather forecast combined with the plant protection advice.

An increasing number of growers want to utilize the computer in their work. They want to apply it to as many purposes as possible, and this survey indicates that a great number of farmers will soon be interested in not only information like plant protection and weather forecasts, but also other forecasts and routines from a central database.

85% of the growers who returned the questionnaire wanted to continue in 1991. A number of the growers who acted as observers at the start of the project in 1982 are still active in the project. This indicates that the farmers take great interest and show enthusiasm in participating in the development of a practical warning system for pests and plant pathogens in cereals.

From the number of returned questionnaires and some of the answers received from the advisers, it is clear that the data connection to the extension service did not function according to expectation. The reason for this is partly of technical nature and partly based on lack of knowledge in data technology among the advisers. Those offices which succeeded technically and had the capacity to learn the functioning of the software found the data programs to function as they should and that they could retrieve weather forecasts and useful information on plant pathology from the NORPRE host computer. Some of the extension units utilized this possibility, daily whereas most contacted the host computer only weekly. Our experience from 1991 (Magnus et al, 1991) is that the services we offer via a PC host computer and bulletin board have been in great demand. In 1990 the distribution of weather forecasts from the Norwegian Meteorological Institute was the most popular service with the extension units.

Preliminary results from the 1991 survey indicate that most of the technical problems with the data connection to the extension services are solved and that our data program instructions have enabled the advisers to retrieve both weather forecasts and plant protection information.

About 50% of the advisers transferred the files from the host computer to their own PC for later use. Those that operated the data programs directly towards the host computer did this only to get a quick overview over the disease, pest and weather situation in the whole county or in their own district. For this purpose such a direct operation may be the most economical considering both time and telephone expenses. Transferring the files to the user's computer would, however, be a more efficient procedure to extract more detailed information.

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VALIDATION OF 'NORPRE' WHEAT AND BARLEY YIELD LOSS MODELS

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ABSTRACT

NORPRE plant protection warning system for cereals is based on farmers observations in the field. Disease and pest countings are compared with a set of threshold values for the respective development stage of the host plants. Field plot trials and yield recordings in practical fields form a feed-back to the warning system. The performance of the models has been evaluated in 1990. Both the field plot data and the farmers yield figures support the threshold values used in the system. A model using the combined relative disease values explained 72 % of the variation of the yield increase after fungicide application according to disease warnings. Negative warnings proved to be correct. Also spraying with fungicides according to NORPRE warnings were largely correct.

KEY WORDS: Threshold values, Yield, Wheat, Barley, Monitoring

INTRODUCTION

The aim of the 'NORPRE' warning system is to give individual recommendations for plant protection in cereals. The recommendations are based on the farmer's current information about disease and pest levels in each field. Due to the specific nature of these recommendations, the risk of misuse and overuse of pesticides are expected to be very much lowered. Benefit from the use of pesticides are nevertheless secured.

The operation of the system is based upon the farmer's monitoring of the diseases and pests in his fields. Sampling and monitoring are conducted according to expected disease and pest development. In principle the farmer should never expect the situation to grow out of control if he follows the advices. All the data furnished by the participating farmers are used to produce daily updated reports. The reports are distributed in electronic form to all extension offices as a form of 'nowcast'.

The individual advices are based on the comparison of the farmers information with threshold values. If one or several threshold values are exceeded, then a recommendation to spray is issued. The simple models used were validated in two different ways. Ordinary field trials with replicates and recording of yield in practical fields. Both procedures provide ample feedback to the operational system. Threshold values may be modified according to analyses of the performance of the system. This paper describes the field trial results and the yield results of the participating wheat and barley fields for 1990.

THE OBSERVATIONS

Table 1 shows the magnitude of the activities in 1990. The yield was registered in 60 % of the winter wheat fields and in 70 % of the barley fields.

Table 1. Distribution of NORPRE-fields in 1990 per host plant

Cereal	Number of fields: Total	Number of fields: with yield registration	Number of observations	Kg per daa
Winter wheat	10	6	53	576
Spring wheat	113	70	477	529
Barley	234	164	849	464

FIELD TRIALS

Three field plot trials where conducted in spring wheat; one field was treated with fungicides twice. Fig. 1 shows that spraying according to warning compared with unsprayed gave partly great yield increases. The field plots were treated against mildew, yellow rust, aphids and glume blotch. In barley, seven field plot trials were conducted. Warnings against mildew, barley scald, net blotch and cereal leaf miner had been issued for the fields were the field plot trials were placed. Disease and pest figures are given as relative values. For the respective development stages the attacks are defined as number of leaves with damage in per cent of threshold values for the disease and pest indicated. Spraying is recommended when the relative value exceeds 100. Relative figures between 75 and 100 are interpreted as 'wait and see'. The yield response for spraying was greatest for high yield levels (fig. 2).

Fig 1 Wheat yield (kg/daa) in field plot for untreated/no warning and treated with fungicides or pestisides after warning

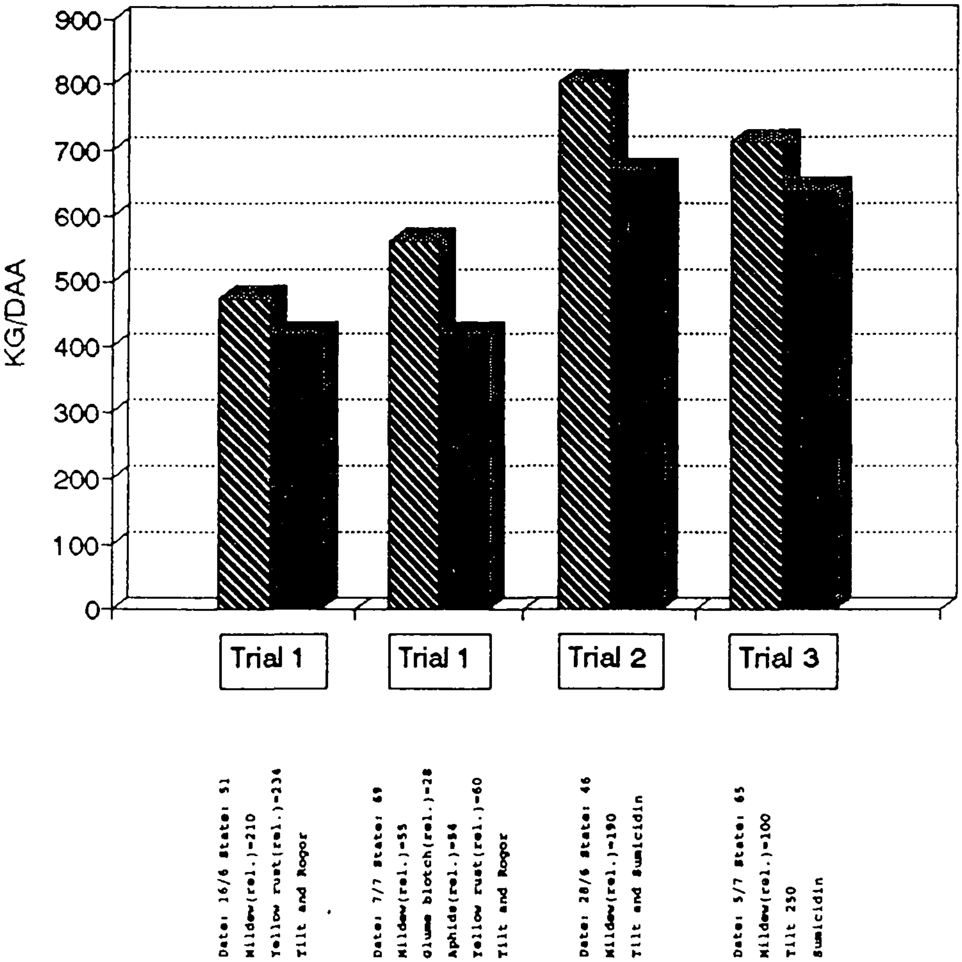
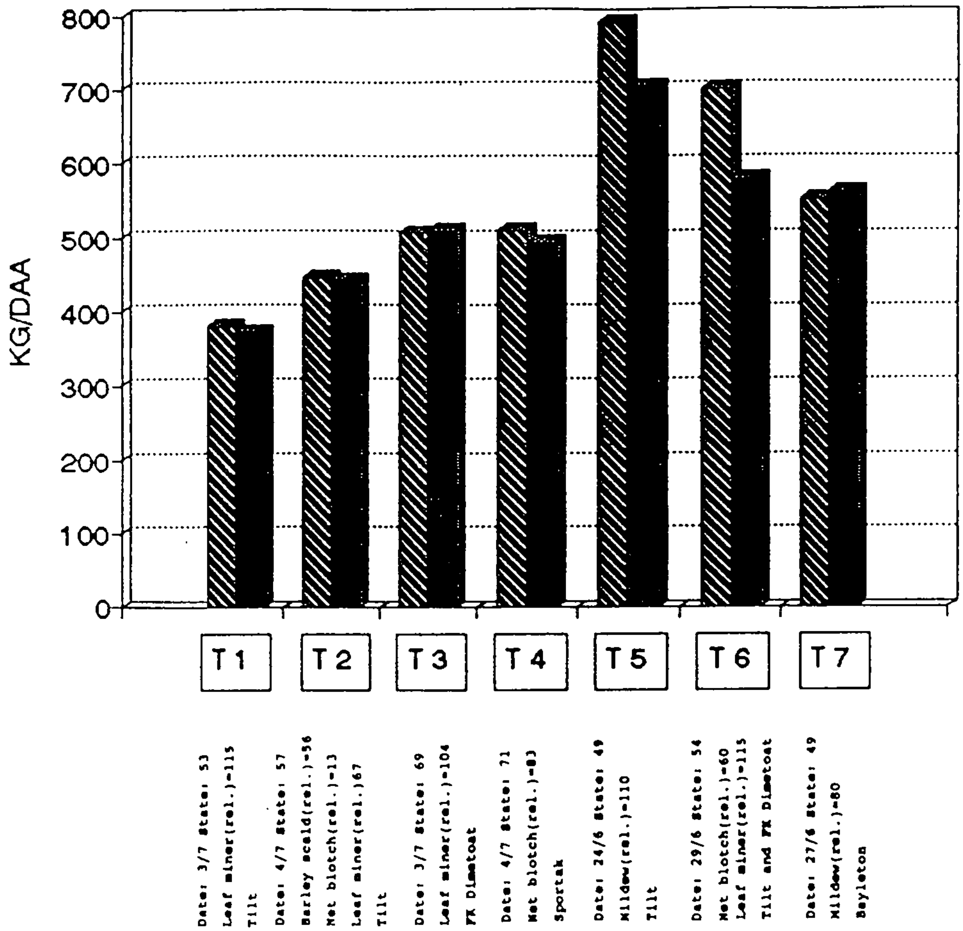


Fig 2 Barley yeild (kg/daa) in field plot for untreated/no warning and treated with fungicides or pestisides after warning



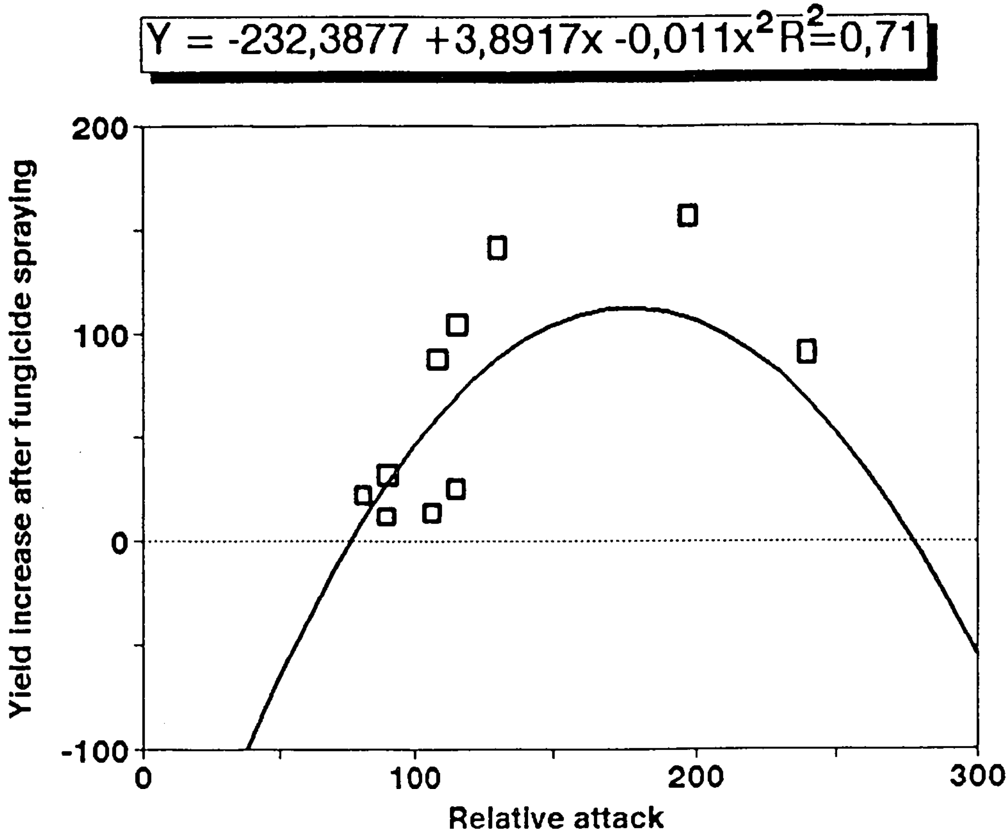


Fig. 3. Yield increase after fungicide application in wheat and barley in relation to sum of relative disease attacks.

Because there were few of experiments in each crop, all data were pooled. Fig. 3 shows the distribution of yield increases in 10 field plot experiments in relation to the sum of relative disease attacks at the time of spraying. Seventy-one per cent of the variation in the yield increase can be explained by a simple equation of second order. Fig. 2 shows that when relative attacks are high at the time of spraying, yield responses are lower than at intermediate values. The choice of 100 as the threshold value seems to fit very well to the material.

DISTRIBUTION OF NORPRE FIELDS ACCORDING TO WARNING TYPES AND FARMERS RESPONSES

The fields are grouped in four categories according to the warning types issued. They were also grouped according to the farmers responses to the warning. The yield results in table 2 and table 3 cover great geographic variations which makes the comparisons difficult. The figures are also uncertain because of varying number of fields in each group.

The number of winter wheat fields is too small to interpret. In spring wheat (table 2) it appears that for the combined data for the whole country, spraying with a suitable fungicide has given a large yield increase compared with untreated (48 kg/daa). With this type of grouping of the fields one must bear in mind that the fields that were treated against our advice not to treat, easily could be misinterpreted. The six fields with an average yield of 536 kg/daa (only 5 kg less than for spray recommendation and spraying) could as well belong to the group 'warning' as to the group 'no warning'. This is so because early treatment with a fungicide would prevent any disease to develop into an attack that would release a warning issue. The same precaution does not apply to the comparison between 'no warning/not sprayed' and 'warning/sprayed'. Although the material is somewhat limited, there is a tendency to a positive response of the spraying in this comparison.

Table 2. Distribution of yield (kg/daa) in 70 spring wheat fields according to warning type and fungicide treatment. Figures in parenthesis are number of fields. Yield is given as kg/daa with 15 % moisture.

Warning type	No fungicide	Fungicide
No warning	466 (5)	536 (6)
Warning	504 (11)	540 (48)
Average	492 (16)	540 (54)

The barley yield responses to fungicide treatment according to disease warnings (tab. 3) were comparable to those in spring wheat. Also the barley material showed that the category of 'no warning/fungicide treatment' contains data which might belong to the group of fields that received a disease warning. Early fungicide treatment of a field will mask the membership to either group ('no warning/warning').

Table 3. Distribution of yield (kg/daa) of 164 barley fields according to warning type and fungicide treatment. Figures in parenthesis are number of fields. Yield is given as kg/daa with 15 % moisture.

Warning type	No fungicide	Fungicide
No warning	441 (66)	502 (11)
Warning	444 (54)	530 (33)
Average	442 (120)	523 (44)

CONCLUSION

Both ordinary field plot trials and yield records from practical NORPRE wheat and barley fields indicate that the threshold values used in our models, give satisfactory results for the yield responses. Also the negative warnings are apparently correct for the material studied so far.

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THE DANISH PLANT PROTECTION RECOMMENDATION MODELS FOR CEREALS

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ABSTRACT
Model structure in the Danish recommendation models for diseases and pests in cereals are described. Models are based on the thresholds relating to the field specific agronomic conditions, weather data and the growth stage of the crop. If a treatment is required, the system recommends a list of pesticides with a calculated dosage most effective to the specific problem. Dosage calculation depends on the infestation level, growth stage, specific effect of pesticide, target and the need for long term effect. Testing of the recommendation models in 1991 has shown that the models can effectively control pests or diseases by recommending a lower dosage with fewer number of sprays, compared to the traditional practice. The recommendation models together with a PC-based information system is expected to be an useful tool in reducing the pesticide consumption.

KEY WORDS: Recommendation model, Cereal, Pest, Disease, Dosage calculation, Field test.

INTRODUCTION
In 1987, the Danish Parliament decided on an action plan for pesticide consumption. The plan aims at reducing the pesticide consumption by 50 % by January 1997 in terms of the total amount of active ingredients and the treatment index (Σ(used dosage/approved dosage)). In order to reduce the pesticide use, without affecting the yield, various biological and climatic factors must be taken into account. In this connection, the use of computer-based decision support systems can be of good help. The Research Centre for Plant Protection, therefore, has developed an information system that can be of help in decision making (Murali, 1991; Secher 1991).

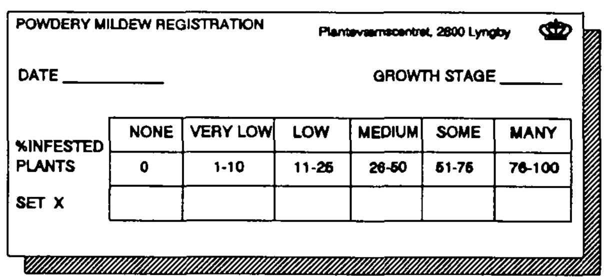
In order to be acceptable to the farmers, it is important that such systems are easy to use. The user-interface must be standardized and transparent for the different models. The registration techniques must be simple or substituted with automatic registrations and the models performance must be reliable and robust.

The Danish system, on the basis of field specific agronomic conditions and field registrations, recommends treatment if needed and the next field registration date. If a treatment is required, the system recommends only the approved pesticides at a calculated adjusted dose. The dosage calculations are specific to each pesticide and the dosage is lower than the approved dosage.

FIELD REGISTRATION

Recommendations are field specific and are based on the threshold values relating to the different agronomic factors. Therefore, field registrations are essential for most of the diseases and pests in evaluating recommendations. Diseases which are difficult to recognize or the epidemic development requires treatments before the disease is observable, will be evaluated through the observation of secondary factors such as precipitation. In cereals, powdery mildew *Erysiphe graminis*, rust diseases *Puccinia spp* and pests *Aphodoidea* and *Oulema spp* requires field registration. Models for other leaf diseases such as *Septoria spp*, *Rhyncosporium secalis* and *Drechslera teres* are based on the precipitation records.

Field registrations are done by estimating the incidence level of diseases or pests. To simplify, the incidence level has to be quoted only in groups for example 0, 1-10, 11-25, 26-50, 51-75 or 76-100 percent plants with attacks. Upto the growth stage 31 (Zadoks et al. 1974), incidences are estimated on the whole plant. While from the growth stage 32, incidences are estimated on the upper three leaves on the main shoot or straw with tillers. In Figure 1 is shown the incidence levels used for the registration of powdery mildew.


POWDERY MILDEW REGISTRATION   Plantevaernscentret, 2800 Lyngby

DATE ________   GROWTH STAGE ______

	NONE	VERY LOW	LOW	MEDIUM	SOME	MANY
%INFESTED PLANTS	0	1-10	11-25	26-50	51-75	76-100
SET X						

Figure 1. Example of field registration. Powdery mildew in cereals.

BASIC STRUCTURE

The use of incidence groups in the registration simplifies the model structure. Thresholds can then be expressed in tables according to the incidence groups and the various growth stages. For each disease or pest is established a number of tables with thresholds depending on the agronomic and climatic factors (Secher, 1991). The various models in the system are interlinked so that the presence of other diseases or pests affects the actual threshold. In Figure 2 is shown the different thresholds for aphids in winter wheat.

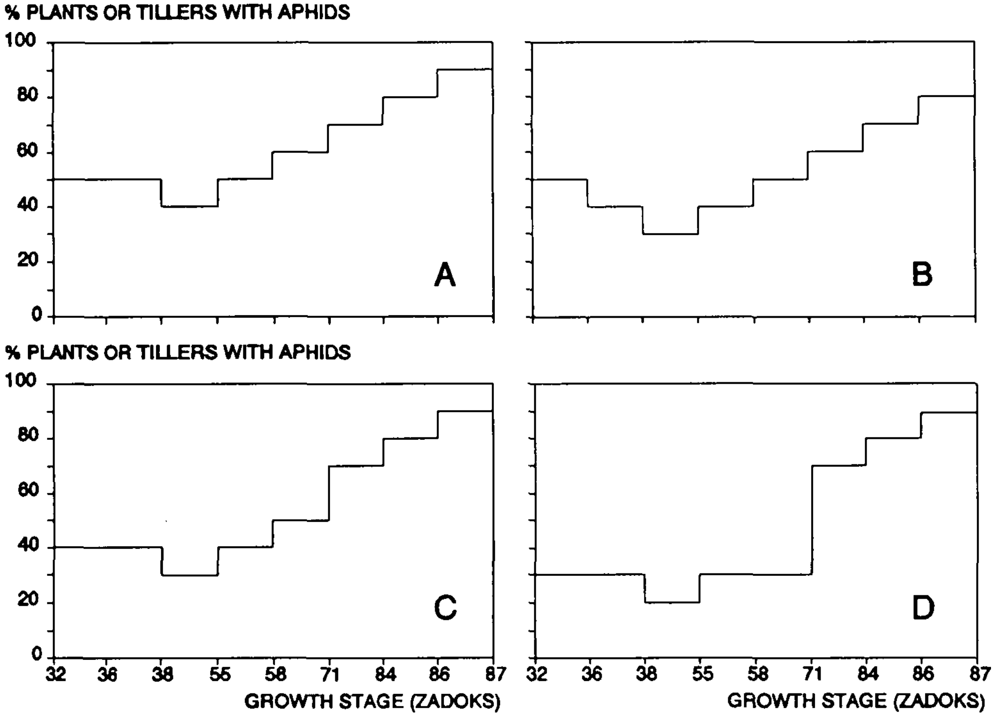


Figure 2. Thresholds for aphids in winter wheat. A = Normal conditions. B = Five days weather forecast - warm and dry. C = Oulema spp. incidence level just under its threshold. D = When the field is to be treated with a fungicide.

Based on the field observation, the specific thresholds for the actual field and the growth stage, the model evaluates if a treatment is required. In Figure 3 is shown the main steps in the recommendation model.

CHOICE OF PESTICIDE

If a treatment is required, the model recommends pesticides approved by the Research Centre. The choice of pesticide depends on the diseases and pests that trigger the treatment and other diseases and pests that are present.

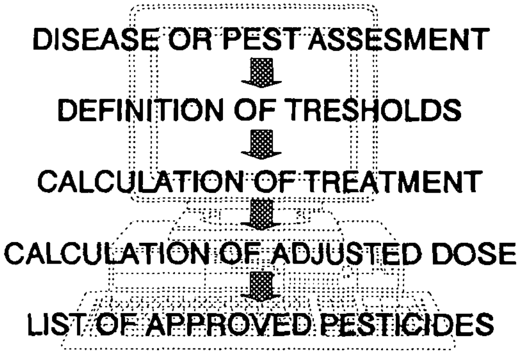


Figure 3. Various steps in model function.

DOSAGE CALCULATION

For each recommended pesticide, specific dosage is calculated taking into account the following factors:

- disease or pest to be treated
- infestation level or risk assesment based on the precipitation
- growth stage of the crop
- specific effect of the pesticide on disease or pest
- whether or not a long term effect is desired

Dosage is calculated for each combination of pesticide and the damaging agent. The final recommended dose is the highest of the calculated dosages. According to the disease or pest and the registered infestation level, an initial dosage is selected. Experiments have shown that various diseases have different pesticide requirements for an effective control. The initial dosage is then adjusted according to the growth stage of the crop. In Figure 4 is shown the adjusting factor as a function of growth stage. Finally, the dosage is adjusted according to the specific effect of the pesticide. The dosage is calculated using the following equation:

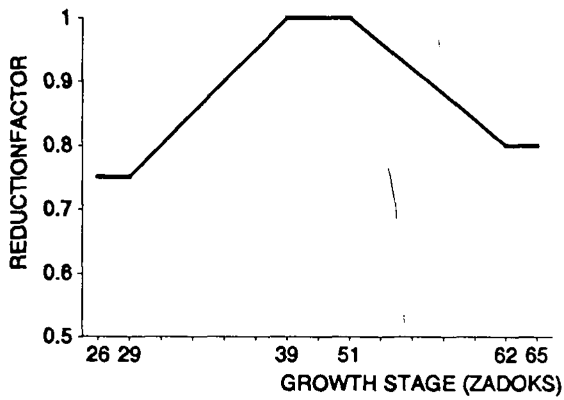


Figure 4. Reduction factor according to the growth stage of the crop. Used to adjust the initial dosage.

$$Dose_{RE} = Dose_{ADJ} * (Eff_{OPT}/Eff_{PES})$$

$Dose_{RE}$	=	Dose recommended
$Dose_{ADJ}$	=	Dose adjusted for growth stage, incidence level and the damaging agent.
Eff_{OPT}	=	Optimal effect obtained by the most effective pesticide
Eff_{PES}	=	Specific effect obtained by the pesticide in question

As the equation indicates, recommended dose will be either the same or higher than the calculated dose with the most efficient pesticide.

In relation to these factors, the recommended fungicide dosage can be down to 1/5th of the approved normal dosage. Similarly, the insecticide dosage can be down to 3/4th of the approved normal dosage.

TEST OF RECOMMENDATION MODELS

Recommendation models were field tested in 1990 and 1991. Test results from 1991 are presented in Table 1. The best combination of fixed treatment in barley is the average of 1, 2 or 3 fungicide treatment(s) with or without insecticide, and in winter wheat it is the average of 2, 3 or 4 fungicide treatment(s) with or without insecticide (Jørgensen, 1991). Neither in spring barley and winter barley nor in winter wheat, there was any significant difference in the yield between model recommended and best combination of fixed treatments.

DISCUSSION

The described model system is although simple in structure, contains a large amount of biological information. Some submodels are preliminary and more detailed models are under development. Ongoing research is being carried out, especially to improve the dosage calculations.

The complete information and recommendation system has been evaluated by a number of agricultural advisors in 1990 and 1991 (Murali 1991, Secher 1991). Evaluations were positive and the system was well received.

Recommendation models have shown good performance in two years field testing. The testing has shown the models ability to react satisfactorily in a year with a high and in a year with a moderate treatment needs.

TABLE 1. Net yield and yield response (treatment cost subtracted) in the best combination of fixed treatments and recommendation models in spring barley and winter wheat. Fungicide in barley: Fenpropimorph + Prochloraz; in winter wheat: Fenpropimorph + Propiconazol. Both crops at 1/3rd dosage in fixed treatments. Insecticide: Pyrethroid. Treatment index = Σ(used dosage/approved dosage).

Treatment	Number of treatments fungic.	Number of treatments insect.	Treatment index	Yield and net yield reponse Hkg/ha
Spring barley (16 trials)				
Untreated	0	0	0	56.9
Best combination of fixed treatments	2.25	0.75	1.42	2.8
Recommendation model	1.41	0.06	0.62	2.3
Average farmer 1991 (1378 fields)	1.57	0.31	0.91	-
Winter wheat (14 trials)				
Untreated	0	0	0	68.5
Best combination of fixed treatments	3.43	1.00	2.03	4.8
Recommendation model	2.25	0.14	0.93	4.2
Average farmer 1991 (1334 fields)	3.61	0.58	2.04	-
Winter barley (4 trials)				
Untreated	0	0	0	67.0
Best combination of fixed treatments	2.25	1.00	1.68	4.5
Recommendation model	1.50	0	0.64	3.9
Average farmer 1991 (431 fields)	2.41	0.04	1.18	-

In 1991, if the models had been used by all farmers, there would have been a 45% reduction in the pesticide use in cereals. In this context, the new system would be a usefull tool in reducing the pesticide consumption.

The use of reduced "appropriate" doses in plant protection strenghtens the demand for recommendation models to be robust, since the gap between a successful treatment and failure is getting narrower. A key point in the recommendations is the registration techniques. They must be a dependable method to translate the field conditions to a standardized figure used in the models, and at the same time be quick and easy to carry out. For a calculated "appropriate" dose to be used in general pesticide applications, registration techniques will have to be standardized, simple and generally accepted by the farmers and the advisory service. In the present system, the methods are simple but further work is required to improve the techniques.

In addition to the knowledge generated in developing the recommendation system, we have experienced that the development has become a common denominator for most of the work carried out at the Research Centre. Also, there has already been a significant dissimination of knowledge from the system through the general recommendations and newsletters.

The information system will be integrated with a similar system being developed for weed control, and the integrated system will be distributed as a module in "The Integrated Farm Management System" developed by the Danish Agricultural Advisory Centre (Murali & Secher, 1991).

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AN INFORMATION SYSTEM FOR INTEGRATED PEST MANAGEMENT AND INTEGRATED PRODUCTION ON ORCHARD AND VINEYARD IN EMILIA-ROMAGNA (ITALY)

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ABSTRACT

The "Regional project for the diffusion of integrated pest management in orchards and vineyards" is a program of experimentation and extension of integrated pest management and integrated production techniques organized by Regione Emilia-Romagna. In 1990 the program involved 14,700 hectares of fruit orchards and 5,000 hectares of vineyards covering about 4,500 farms. In 1991 the program has employed 196 technicians. A specific computer network is used to collect and process the data obtained from the farms and to supply meteorological data to the technicians. Videotex is also used for extension service and meteorological data.

KEY WORDS: information system, plant protection, integrated pest management, integrated production, advisory services.

INTRODUCTION

Emilia-Romagna is one of the leading areas for fruit and grape vine cultivation in Italy. The area under fruit cultivation is 96,000 hectares (mainly peach, pear and apple).Vineyard area, for wine production, is 71,300 hectares.

The "Regional project for the diffusion of integrated pest management in orchards and vineyards" is a program of research, field experimentation and extension of integrated pest management (IPM) and integrated production (IP) techniques. This program is organized by the regional administration, Regione Emilia-Romagna (RER) with the financial contribution of the Ministry of Agriculture and Forestry and of the European Community (for specialistic training of the technicians).

The project was launched in 1973, starting with a period of preliminary testing of IPM methods. After this period, in 1980, a demonstration and application phase to put these methods into practice was begun. Next step will be the development and application of integrated production techniques.

In 1990, approximately 14,700 hectares of fruit orchards (peach, apple, pear, plum, apricot and cherry) were directly involved (more or less 20% of the regional fruit surface), as well as 5,000 hectares of vineyards (7-8%), covering over 4,500 farms.

In 1991 the program has employed 196 technicians, occupied with technical advising (144) and experimentation (40) about integrated fruit and vine production, with particular care to integrated pest and weed control and fertilization (as well as with all the other principal agronomic techniques).

Among these technicians, 12 work as coordinators and are responsible for provincial technicians meetings during which weekly bulletins are drawn up. The bulletins are printed and recorded on telephone answering machines. They are also published on local newspapers, as well as by videotex.

The introduction of IPM techniques in fruit and vine production has led to an average reduction of about 30% in the number of treatments, quantities of pesticides used and pest control costs, compared with farms practicing traditional pest management. Furthermore, this initiative has had a considerable influence on the type of protection methods recommended by other agricultural techncians in RER, thus contributing to more rational pest control strategies on a much larger scale than the one which is directly affected by the project.

IP GUIDELINES

The guidelines at present applied to the control of the principal fruit orchard and vineyard pests and diseases consist of a general frame of samplings and classic IPM decision-making systems (based on economic thresholds, use of selective and biological pesticides, natural biological control and forecasting models). As to the other agronomic techniques (i.e. fertilization, weed management, irrigation, cultivar choice, etc.), a list of rational practices is also advised (Malavolta et al., 1990; AA.VV., 1991).

Two kinds of farms are distincted:
- pilot farm: data collection is related mainly to information system with particular care to precise, exhaustive sampling and technical information; their number is of 450-500 (1,400-1,500 orchards and vineyards).
- newly involved farms and expert farms: technical advising requirements are more important than the quality of collected data.

Pilot farms are required to be visited by the technician once a week, the others less frequently, according to their level of autonomy.

Samplings about pests, diseases and beneficial organisms are carried out weekly on shoots, leaves and fruits; sex and chromotropic traps are also used.

Sampling results and the other following data are noted on appropriate forms:
- farm location (geographical and administrative);
- orchard and vineyard general agronomic information (surface, cultivars, rootstocks, age, plantation and rearing system, soil features and management, spray machine employed);
- plant development (phenological phase);
- agronomic techniques applied (fertilization, weed management, thinning, pruning, irrigation);
- pests, diseases and beneficial organisms populations;
- plant protection treatments applied (commercial products, doses, volume of solution distributed, partial applications)
- harvest information (date, damages, quantity and quality);
- local rainfall (measured by means of farm pluviometer).

The justification and correct timing of treatments are always required: by means of economic thresholds for pests and by observation of climatic conditions favourable for diseases. The forecasting models at present applied are the following:

- diseases infection and treatment timing: apple scab and grape mildew;
- pests treatment timing: thermal sums for codling moth (*Cydia pomonella*), peach fruit and twig borer (*Grapholitha molesta* and *Anarsia lineatella*), grape fruit moth (*Lobesia botrana*) and leafrollers (*Pandemis cerasana*, *Archips podana* and *Argyrotaenia pulchellana*).

After the first period of the project development it has resulted that four main problems had to be solved in order to obtain the initial target of applying IPM and IP techniques on 50% at least of the regional surface:

1) to make possible and optimize the use of agronomic and climatic data for IPM and IP application;
2) to increase the amount of farms practicing IPM and IP techniques;
3) to improve IPM and IP methods;
4) to permit management, checking and future planning of technical advising, extension services and research.

THE INFORMATION SYSTEM

An information system (IS) was designed and experimented by RER, starting from 1987, to solve the above mentioned four problems. This work has been done in collaboration with the Advanced Service Centre of the Centrale ortofrutticola di Cesena and of the Agricultural Engineering Institute of the University of Bologna. In 1989 a computer network and a specific software were installed to collect and process the data obtained from pilot farms and to supply meteorological data to the technicians on real time (maximum delay 12 hours).

A Regional Agrometeorological Service (managed by ERSA, Regional Body for Agriculture Development) has been working since 1983. It provides climatic data on real time (every two hours) from 25 automatic electronic stations and other climatic data from manual mechanical stations. This service provides also weather forecasting. In order to permit a better processing of meteorological data, laking data are estimated and re-built before their diffusion.

Data from pilot orchards are collected on "real time" (maximum delay, 1 week); data from farms practicing traditional pest management are added in autumn-winter in order to have more significant statistical analyses and comparisons.

A checking procedure on field permits to validate the content of data base. This activity consists in executing controls on forms and in the fields, by randomly choosing the farms to be checked.

The general structure of IS is designed according to the different requirements of technicians:

- technical advisors: they need mainly meteorological data for forecasting models and simple processing of their own agronomic data;
- provincial coordinators: they need to have at their disposal know aggregated (or not) and processed agro- and meteorological data of their own provinces to drawn up the provincial bulletins;
- regional coordinators and scientific advisors: they employ regional agro- and meteorological aggregated (or not) data for general coordination and development of IPM and IP techniques.

The logic data flows are syntetized in fig.1.

The computer and videotex network installed permits agronomic and meteorological data flows according to the above mentioned needs.

The network is based on MS-DOS personal computers (PC) of different performances for data-entry and processing:

- at periferic level low-medium performances PCs (65 installations) are supplied directly by cooperative fruit and vine stores and by agricultural department offices;
- at provincial and regional level 80386 PCs (9 installations) are mainly employed.

A Digital VAX computer works as electronic mail host: all the PC modem connections employ this central service. For short distance data transfer by diskette is also applied.

The data-entry software for agronomic data permits the input of original and codifies them automatically. A powerful on-line help makes the use of SW friendlier. Data are directly entered by technical advisors after a specific one-week training course.

Data-entry and data processing SW are written in Clipper language managing DBaseIV-like files. This permits the use of SQL procedures in different data base environments.

The connection SW is Decnet-DOS by DEC.

At present the IS supplies two principal kinds of agronomic data output: management and technical.

The management outputs are:

- printing of forms;
- summaries of farms involved in different geographical areas and their features.

The technical outputs are:

- comparison between IP farms and traditional farms in terms of pesticide application (number, quantity and costs); data are disaggregated in insecticides, fungicides and acaricides;
- analyses of treatments against single pest and disease;
- analyses of active ingredients applied against single pest and disesase;
- analyses of pests, diseases and beneficial organisms populations in terms of:
    - % of field with presence;
    - % of field exceeding a defined (variable) population level;
    - % of field exceeding economic thresholds;
    - average population or infection level;
    - % of justified, admitted, advised treatments;
- traps capture flights graphs for the main pests.

Before data processing it is possible to select the sample to be examined by choosing:

- the geographical area and/or single or group of technicians;
- period of time;
- level of updating.

The data processing SW for meteorological data is written in Quickbasic language and provides the above mentioned forecasting models and basic data.

Videotex is also used for basic and processed meteorological data, for weather forecast supply and for bulletin extension. This system permits very low costs of installation and operating; it is also easier to be employed than a PC/modem system and this permits to increase the number of technicians and farmers involved. Another advantage of videotex is the possibility of supplying a lot of further information: as to IP, videotex permits to manage also irrigation (in this case an interactive system is employed based on orchard rainfall data) and fertilization; market information are also available. Some experimentations of direct and interactive videotex connection between farmers and technical advisor is going on with contradictory results.

OBTAINED AND EXPECTED RESULTS

The answers expected from this information system as to the four main problems are:
1) Technicians and coordinators need to know pests, diseases and beneficial organisms populations, mainly on real time, as well as climatic conditions and forecasting. The IS can supply this information and permits to optimize the techniques applied; well trained farmers can also obtain information very easily directly by videotex.

2) One of the major problems in fostering the use of IPM and IP techniques is the need for a direct contact between farmers and technicians. It is strictly related to the farmers capability. Normally, old or not well-trained farmers are not ble to apply IPM by themselves at a sufficient quality level. In order to solve this problem, the experimentation of indirect technical advising is already at an advanced level. This initiative is based on the principle that it is possible to apply IPM techniques to the majority of pests and diseases by means of "real time" area information collected on pilot areas (instead of single orchard information) using information systems for decision making. The extension of the results of area analysis can also be made by using modern means such as videotex, television, etc.. For the remaning pests and diseases, where specific orchard monitoring is required, the management is entrusted to fruit growers.

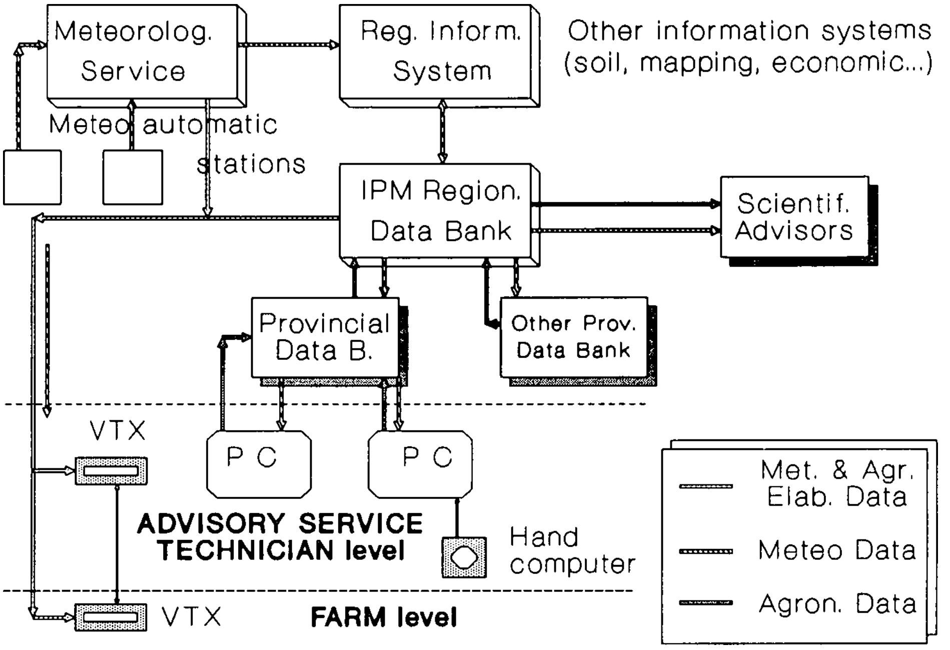
3) Statistical analyses based on a large number of orchards and vineyards will enable to know the average trends of phenomena very difficult to appreciate on small or local scale (i.e. pest distribution, cultivar susceptibility). The

relational data base makes possible the analysis of the relationship between different factors (single or multiple). It will be possible to examine the relation between, for example, the rainfall and the apple scab infections in presence of different soil conditions. The information system is designed to permit the connection to other regional and national ISs. Geographical coordinates will enable to analize the influence of soil contents on pest population development or the mapping of phenomena such as the distribution of diseases. In general it is expected an impulse on forecasting model research also for best opportunities of validation at low costs of the models on a larger number of conditions.
4) The data processing permits to know during the season the statistical information about the farms involved, their number and distribution. It makes also possible the application of checking procedures to point out particular dynamics in technical behaviour. Updated and easily processable information are extremely important also for planning of technical advising, extension services and research and experimentation programs.

FUTURE DEVELOPMENTS

The main developments planned in close future are:
- the changing of regional data base from DOS operating system to UNIX (i.e. Oracle or similar);
- the employ of TCP/IP protocol for connection by using a high speed (2Mbps) network;
- further integration to other ISs;
- the use of pocket computers for orchard and vineyard sampling and for farm meteorological data input and processing;
- videotex data-entry;
- development and use of pest forecasting models such as time-varying distributed delay phenological models (Baumgartner & Severini, 1987);
- development and use of disease forecasting models such as Potential Index of Infection models (Schroedter H., Ullrich J., 1965,1966);
- development of the processing SW with particular care to data selection for multiple factor analyses;
- the use of quantitative weather forecastings.

Fig. 1



LOGIC DATA FLOWS OF THE IPM IS in Regione E. R.

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WORKSHOP ON COMPUTER-BASED PLANT PROTECTION ADVISORY SYSTEMS
COPENHAGEN 27-29th NOVEMBER 1991

TWO EXAMPLES OF RECENT AGROMETEOROLOGICAL STUDIES ON CEREALS AND VINEYARD PROTECTION IN FRANCE

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ABSTRACT : Several studies have been done in France for the last recent years in the field of forecasting models and micro-computer program aimed to improve crop protection management : two examples are discribed. One concern a computer program based on recent vine deseases and pest forecast models tested in practical conditions on a vineyard in Bordeaux area (chapter A). The other is about a recent wheat Brown rust forecast model carried out by D. Caron from ITCF in France (chapter B).

KEY WORDS : Cereals, Vine, Forecast models, Brown rust, Computer program

A - METEOPRO : A MICRO-COMPUTER PROGRAM TO HELP DECISION MAKING FOR VINEYARD PROTECTION AGAINST DESEASES AND PESTS (RESULTS OF THREE CAMPAIGNS)

I - INTRODUCTION :

One of the most promising ways to manage vineyard protection against diseases and pests, derives from the researchs which have been carried out for the last ten years in different European countries, mainly in France, in the field of deseases (Grey mould, Downy mildew, Black-rot) or pests (Grape moth) forecasting models.

At the same time, when models were elaborated and validated, automatic weather stations (Cimel trade mark) wich can be linked by phone to a micro computer have been finalized. They can get and store a few days into their memory (or more in a reprom memory) climatics datas such as rainfall, relative humidity, wetness duration, temperature, all aviable to be used in calculations of the previous model.

The micro-computer program Meteopro settled by the ACTA allows capture, storage and management of these datas in real time and local conditions for example on a farm itself. It also allows to assess developement of some crop deseases and pests through forecast models and may help the decision for treatments. This way of management does not cancel the possiblity to manage automatic weather stations as a network by a federative structure, Plants Protection Services for example, and on this hand the two ways could be complementaries to spread the concept of integrated crop protection.

The application of the Meteopro system on vinyards in Bordeaux area during three campaigns (1989, 1990 and 1991) has permited to adapt mainly the number of fungicides spraying at the real risks. Other applications on others crops are avaible but not tested at the moment on a large scale.

II - METEOPRO :

This micro-computer program is composed of several parts :

1 - Tansfert : this part allows properly the link between the micro computer and both the automatic weather station, Cimel trade mark or other (not yet tested at the moment), or even other sources of datas. The phone link need however the micro computer to be equiped with à Kortex card.

2 - Datas management : wich permit, as indicated by it's name, to correct datas if necessary, compare them at local normal ones, set up in semi-annual or annual files etc...

3 - Visualization : this part can show all datas on the computer screen, or print them in order to make paper archives. We can also set up with this part monthly or yearly weather statement and build up curves for all climatic parameters.

4 - Forecasting : this is the main part of the program as a helping decision tool. We can with this part automatically calculate different forecast models and mainly for our purpose the following ones on vine topic :

- Downy mildew EPI model from S. Strizyk in it's 1983 version wich is tested in Bordeaux area since this time and wich gave valuable informations for this area. It works with rainfall and temperature in it's winter phase, relative humidity and temperature in it's summer phase (growing phase)

- Grey mould due to *Botritys cinerea* EPI model from the same author, in it's 1985 version wich yet need some improvement to be completely avaliable : temperature and relative humidity are the two climatic parameters used for calculating this model.

- Black-rot model using weatness duration (or duration of relative humidity more than 90 %) and temperature wich is based on Spotts (from Ohio University in USA) laboratory results. This model is tested only since six campaings and gave satisfaction mainly concerning the forecast of contamination on leaves. However studies are running on in collaboration with INRA Bordeaux center (Plant Pathology Laboratory) and Vine Technic Institut (ITV) from Bordeaux in order to make more precise the forcasting of bunches contamination risks.

- Grape moth (*Lobesia botrana*) model based on climatical and biological datas carried out by Touzeau in 1979 : this model works well for the first and the second generation of the pest, but some improvement are needed to have good results about the third one.

III - <u>METEOPRO SYSTEM TESTING</u> :

In may 1989, this "instrument panel" decision helping has been installed at Chateau de Malle Preignac (Bordeaux area) in the context of the "Ecospace" set up by Schering agrochimical company Our aim was to get in practical conditions informations and references about the possibility of using this system and the help management for vineyard protection at a grower level.

A Cimel automatic weather station (Enerco 404 type) was installed on a grassy soil, at the center, of the vineyard. This station is equiped with four sensors able to catch the following climatic parameters : température under shelter two meters above the ground level, rainfall, relative humidity, wetness duration. The central unit of the station is linked with the French phone network by a modem.

Linkage with a micro-computer IBM PS AT (80386) equiped with a fourty megaoctets hard disk and a Kortex card KX 1200 A/PS.

Protection of the frame against the lightning is absolutely needed and also a minimum maintnance is needed only half an hour to an hour monthly (sensors cleaning and mainly the rainfall one).

Phone call of the weather station by the micro-computer has been automated by the help of a clock plug, wich swiches on the last micro-computer at half past seven a.m. It then catches and stores the three previous days climatics datas contained in the memory of the station. This allows first to have daily datas wich are on their own an interesting information. Automation phone call of the station runing even if the user is away is a safe way for catching datas. However it is very important to survey from time to time the validity of catched datas, mainly relative humidity one knowing that this sensor can be out of order.

Calculating Downy mildew risks is also automated after the phone call and catching datas on the hard disk in specialized files. Results are printed and so every morning, during the growing period when decisions are needed in order to manage vineyard protection an actualized informations about thy evolution of risks of downy mildew could be read by the grower. Calculating the other models is not yet automated and is done by hand daily if necessary.

During campaigns 1989 and 1990 according to a same design plots of the vineyard have been protected using to take a decision the informations elaborated by the Météopro system. At the same time other plots were protected in a "classic" way, usually employed by the manager of Chateau de Malle.

As a result, on "Meteopro plots" the number of fungicide treatements (mainly against Downy mildiew) have been adapted at the local risks, rather low in 1989 and a bit higher in 1990. In 1991, the total surface of the vineyard of Chateau de Malle has been protected using the informations from the Meteopro system. So we compared the results with a neighbour vineyard more classically protected.

IV - <u>RESULTS FROM THE THREE CAMPAIGNS OF PRACTICAL USE OF METEOPRO SYSTEM (see diagrams)</u> :

Using the informations elaborated by the Meteopro system has allowed to cut down the number of treatements targeted against desease and mainly against downy mildew. In 1990 for example, "classic" plots (A1, A2, A3) recieved eight treatments against the deseases complex downy mild, black-rot, powdery mildew while at the same time, the Meteopro plot A4 recieved only three with, the same results.

From an economical point of view we can see on figures 1, 2, and 3 that we saved a good amount, about 1000 FF/ha average, during the three campaings.

Figure 1 : <u>Cost of the different ways of protection on Semillon variety in 1989 A4 = Meteopro plot, (results from Ecospace Shering Chateau de Malle)</u>

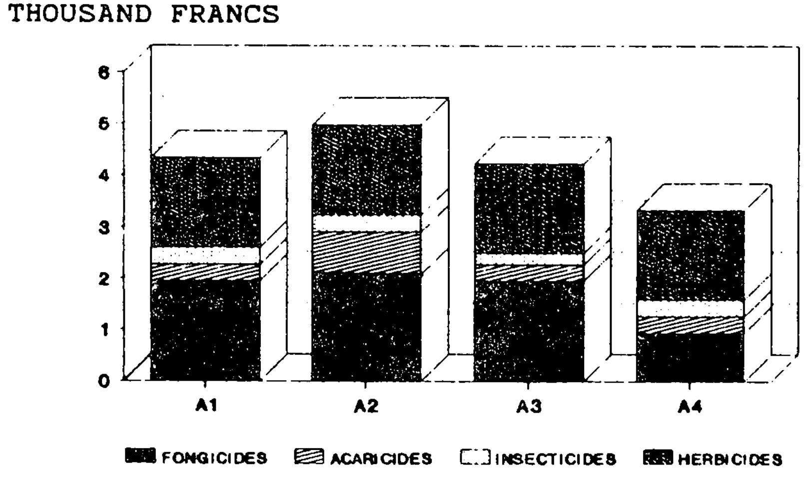


Figure 2 : Cost of the different ways of protection on Semillon variety in 1990 A4 - Meteopro plot, (results from Ecospace Shering Chateau de Malle)

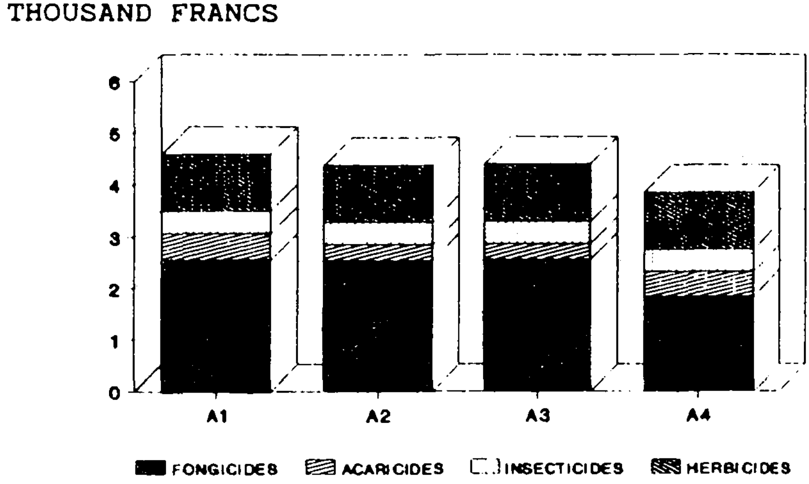
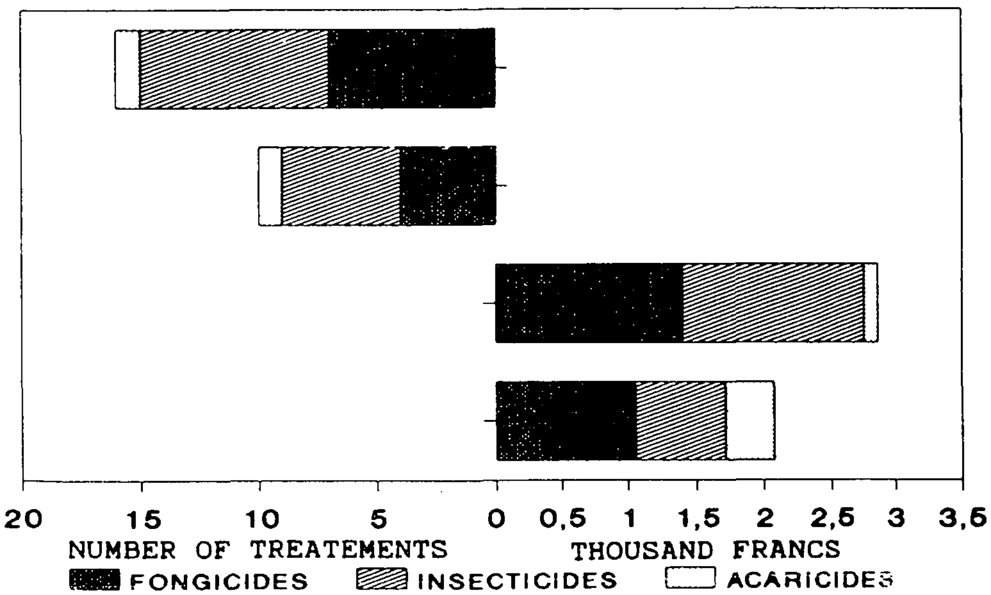


Figure 3 : Comparaison of both number of compound sprayed and cost of them between Chateau de Malle way of protection and a neighbour one in 1991 (results from Ecospace Schering Chateau de Malle)



V - CONCLUSIONS :

Using Meteopro helping decision system to decide treatments for protecting vineyard, as an experience during three campaings at Chateau de Malle has permitted to obtain pratical references about the validity of this system and it's possible integration in the management of vineyard protection.

The possibility of extending such a system needs to check carefuly the constraints attached to this perspective :

- first of all of course well validated models, wich have to be carried out and tested in local conditions during many years before being used at a grower level, are needed,

- climatics datas must be validated too and for this it is absolutely necessary to survey them from time to time on the micro-computer screen, and to have a good maintenance of the sensors,

- the user of such a system is not obliged to have a good knowledge in computer science, however, it is necessary for him to forecast maintenance of computers, compatibility with printer, phone link with the station...,

- it is also most important to interprete in a good way the results of calculations, and curves derived from these results : this needs a few training hours or a good link with specialized agents from Plant Protection Services for example.

Under this conditions, and mainly after the three experiment campaings at Chateau de Malle we can say that the use of Meteopro system lead us to good pratical results and it can allows to help decision making to manage vineyard protection.

B - THE WHEAT BROWN RUST FORECAST TRIANGLE

D. CARON (ITCF France)

I - INTRODUCTION :

Wheat Brown rust is a very dangerous desease wich can have heavy consequences on yield : the loses may be as a result other 4 tones/ha. The epidiomological development may spread very fast, mainly from stage F 6/8 to stage F 11.4 (maturation) according to the year. Due to the short notice, control of the desease, based on systematic program can be, as a result not very efficient.

In order to eliminate this draw back, ITCF has set up a forecast model (Patrouille), the aim of wich is to schedule by calculating, the spraying time. Testing and validating this model, as well as its further handling by technicians or growers, need an easy and immediate presentation and interpretation.

This constraint leads to build the Brown rust "Triangle de prevision" (Forecasting triangle).

II - METHOLOGY :

1 - Forecasting :

The forecast method fall into several phases : we only consider here the last one wich indicate the date of spraying. It is based on relation between climatic conditions and desease behaviour. The duration of relative humidity between 80 % and 100 % at certain periods is the base of its construction.

2 - Evolution of the desease :

Testing experiments are carried out on 20 sm small plots according to a three replicates randomised desing with adjacent control plots. Desease developpement is assessed on these untreated control plots.

3 - Forecasting triangle (see figures at the end) :

It is the mean to transfert forecasting results to users. Desease climat relationships are realised in order to show only the dates of :

- calculation,
- calculated forecaste.

The third side of the triangle (a rectangle and equilateral one), on wich calculating date coincide with forecasted date, point out the final forecaste. Results wich are on the other side of this "final forecast line" (outside the triangle) define date situated in the past, and therefore they can't be used to determine the date of spraying.

III - EXAMPLES OF EVOLUTIONS :

They have been chosen in order to illustrate both a late and unusual evolution of the Brown rust and a "rebounding situation" wich is more usual.

In Montesquieu Lauragais (F 31) during 1989, Brown rust had a late and limited evolution due to drought, in spite inoculum being present during the all campaing. Figures 4 and 6 show the results

In L'Isle Jourdain (F 32) during 1990, inoculum was present and the starting of Brown rust development was stopped by a drought period. It could only start again two or three weeks later. Results are showed on figures 5 and 7.

IV - INTERPRETATIONS :

Forecast triangle help decision to determine spraying time through the forecast calculation.

We decide to treat before reaching the final forecast line in a week long safety zone wich is delimited by the dotted line runing parallel to the straight one.

This final forecast line represente all the points corresponding to a treatement to be done on the same day of calculation : it is the hypothenuse of the forecast triangle.

This triangle can be read in three different ways :

- the date of forecast wich is read on the Y axis after calculation : it is the provisional forecasting date,

- the Brown rust evolution according to the curve drawn with daylies calculated results,

- the earliest date of treatement, thinking that climatics conditions will be the most favorable to the Brown rust developpement : it is "the catastrophe scenario"

The forecast date read on the Y axis after calculation is the simplest and most direct we can do, since, knowing the date of the calculation on the X axis, one just has to read the schduled date of treatement on the Y axis.

We can compare the situation of the point we obtained, according to it's distance from the final forecasting line : the greatest this distance is, the more the forecast obtained may be modified according to future climatic conditions.

The curve obtained with all calculated points give a good idea of Brown rust evolution even if the desease is limited or into incubation.

Curve tending to reach quickly the final forecast line as a perpendicular, means that wetness is the most favorable to permit the maximum epidemiological speed and thus desease can become quickly damageable. On the other hand the calculated points drawing a parallel with the final forecast line means that conditions are unfavorable and Brown rust is completely stopped waiting for better conditions which will permit a new development. The curve can even go away from the forecast final line and in this case, we see on the chart that Brown rust is coming down : it could happen that it is the same on the exerimental plots.

This way of following Brown rust behaviour (and not only by provisional date) gives more informations for decision making because this allows to prepare treatement under good conditions or to do other works without any risks.

Certainly, between the last calculated point and the final forecast line, there is a "virgin zone of undecision ". We can minimise that by calculating "catastrophe senario" giving the maximal speed of Brown rust evolution. There is no need of course to spray before this date because Brown rust must not reach - by hypothese - its quick extension phase before that.

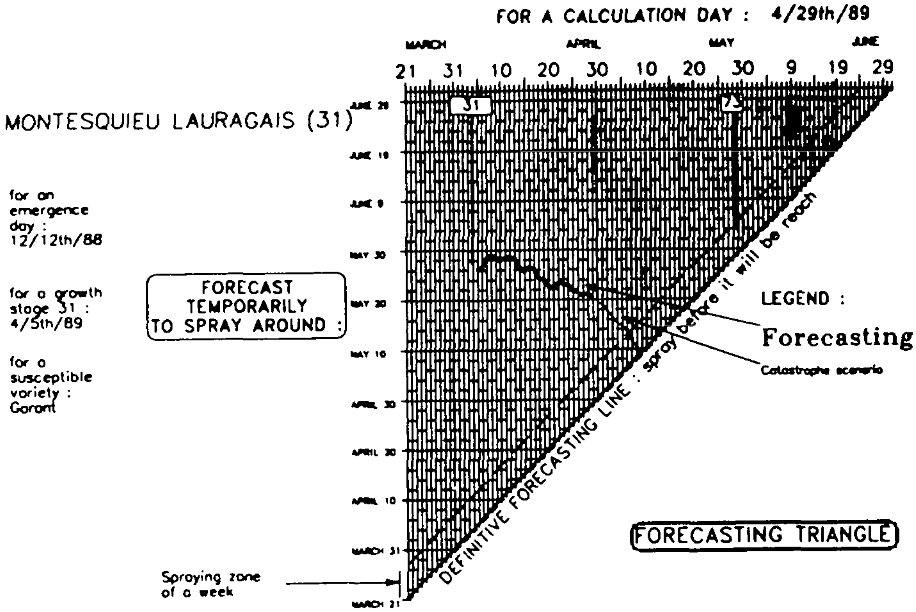
In the case of Montesquieu Lauragais, in 1989, (figure 4), the weather was dramatically dry, exept in april, but at this time, Brown rust was not dangerous because yet rare or into incubation. At the end of april, according to the "catastrophe scenario", we are 10 days before treatement. In this period climatic conditions became dry and unfavorable for the desease wich broke down : it's evolution became limited. As a result, Brown rust level remained small and had no effect about the final yield.

In l'Isle Jourdain (figure 5), in 1990 F6 stage happened early on march 21th. since the winter has been dry and hot. Brown rust was not evoluting at the end of this period and we can see that on the chart. In april some rainfall provoque a faster desease's evolution. Some damages were observed around april 24th. but, because drought, the desease did not develop and even regressed. Aroud may 18th. Brown rust level was the same and most of the spores were not valid and moreover, leaves spots tumors got a dry and lifeless aspect. The evolution of the desease followed the forecasting of it and it was easy to interprete forecasting traiangle.

CONCLUSIONS :

Forecasting triangle help to understand Brown rust calculated forecast It can be read as a result of calculation or interpreted in terms of behaviour of the Brown rust not yet visible or in incubation. Its final aim is to indicate the time when Brown rust developpement becomes faster, according to the fact that it is nessecary to treat before this time. Before seeing this period on the triangle, we can know the date before wich the epidemiological extension is impossible by simulating "catastophe scenario".

Figure 4 : Results of the forecast Brown rust spraying with the help of Forecasting triangle in Montesquieu-Lauragais in 1989



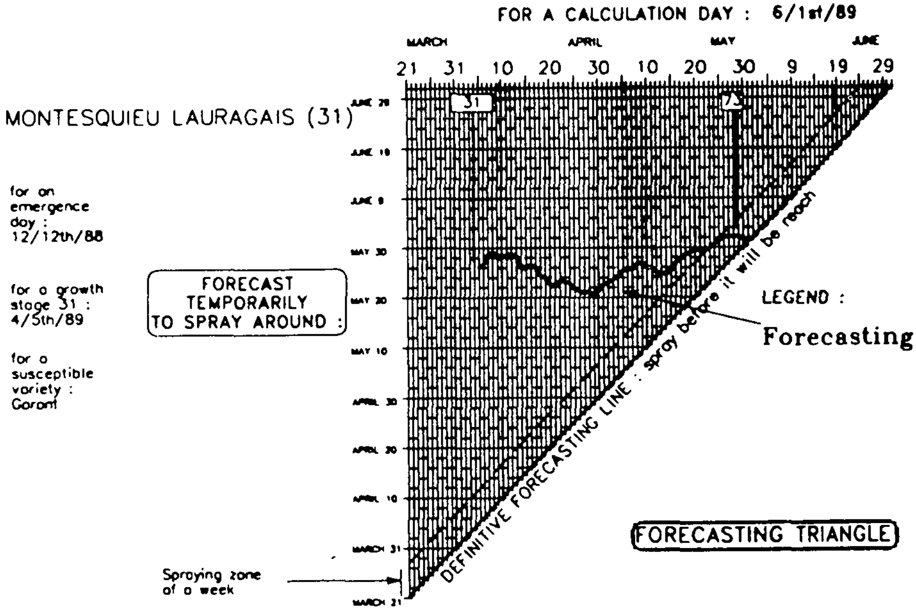
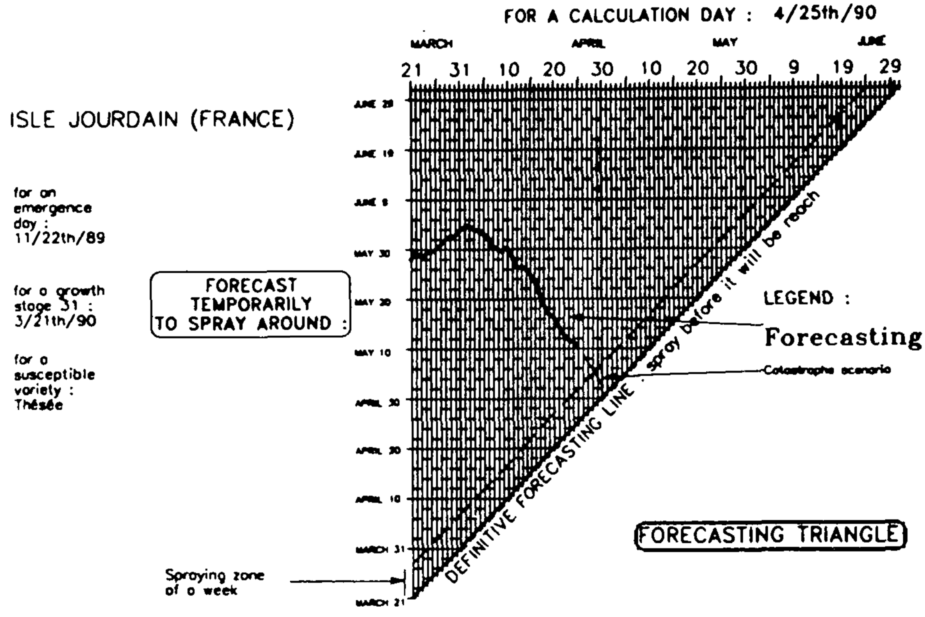


Figure 5 : Results of the forecast Brown rust spraying with the help of Forecasting triangle in L'Isle Jourdain in 1990



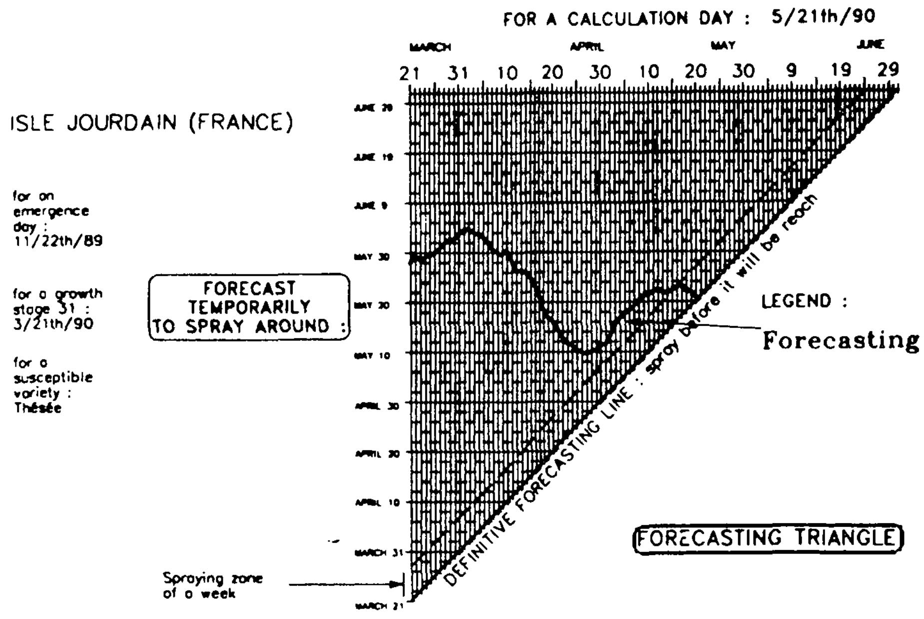


Figure 6 : Brown rust evolution in Montesquieu-Lauragais in 1989

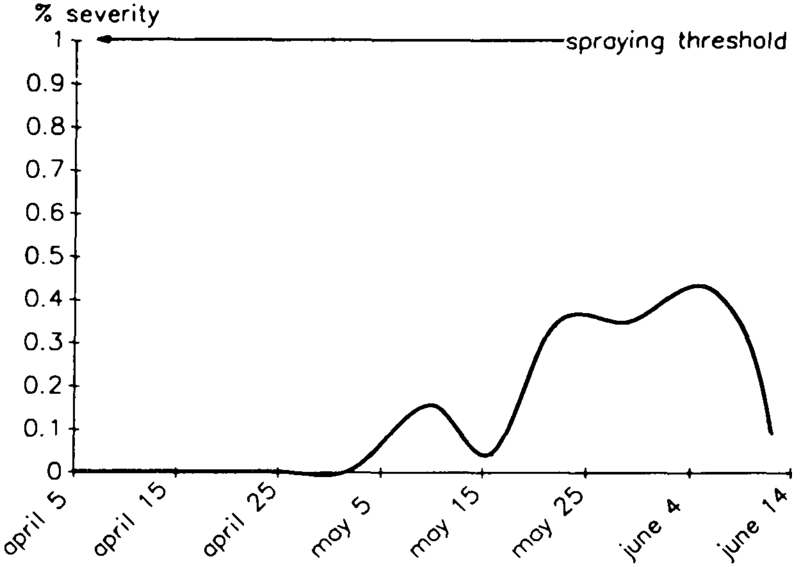
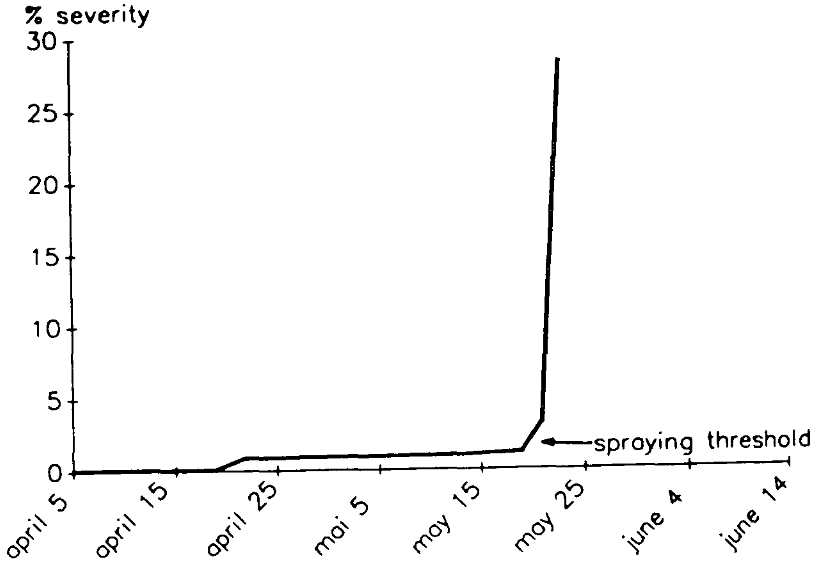


Figure 7 : Brown rust evolution in L'Isle Jourdain in 1990



Workshop on Computer-based Plant Protection Advisory Systems
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SEPTORIA SPP. - USE OF DIFFERENT DOSAGES AND TIMING FOR OPTIMAL CONTROL

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ABSTRACT
The optimal dose and timing of fungicides for control of Septoria spp. has been tested in field trials using EBI fungicides. Different treatments using 3 and 4 applications per season showed acceptable control when using dosages in the range of 1/4 to 1/2 of the normal dose per treatment. In rainy seasons trials results have given unacceptable control using dosages below 0.8 l/ha (normal dose being 1.0 l/ha) if only one single application is carried out in the period between g.s. 32 and 72. If split application is used in this period, 2 applications of 0.3 l/ha, gave acceptable control.

Early season application (g.s. 29-31) with broad spectrum fungicides did not eradicate the disease sufficiently to leave later applications out.

In semi-field trials using artificial inoculation the preventive and curative effect of tebuconazole on *Septoria tritici* and *Septoria nodorum* were tested using reduced dosages. The periode in which optimal control could be reached - decreased when using reduced dosages, however, it still left possibilities of obtaining full control even at 1/4 of the normal dose rate.

KEY WORDS : Septoria spp., EBI-fungicides, dose rates, timing.

INTRODUCTION
Since 1986, there has been an increased interest in Denmark in using reduced dosages of fungicides in cereals. This interest has been intensified by the Danish government decision on reducing the use of pesticides by 50% by 1996.

Trial results have shown good possibility of using reduced dose rates and still obtain acceptable control of wheat diseases without an increased risk of yield losses. A necessity is, however, that treatments are carried out at low disease levels and spray intervals adjusted relatively to the dosages used (Jørgensen, 1989).

Practical farming has, generally, adopted the habit of using reduced dosages which again has increased the number of applications per season. Broad spectrum fungicides with a normal dose being 1 l/ha are today used in an average dose of 0.3-0.4 l/ha per treatment, and instead of using 2 applications per season the number has been increased to an average of 3.3 applications per season (AIM farmstat).

In spring infestation of *Septoria tritici* is seen in almost all Danish fields of winter wheat. A potential risk of yield loss because of this disease exists therefore in all fields. Precipitation later on in the growth season from g. s. 32 (Zadoks) has the major impact on the further development of the disease in the crop. In order to evaluate the disease risk several forecast systems based on correlations between wet weather and disease severity have been proposed (e.g. Tyldesley & Thompson, 1980; Shauer & Finney, 1977, Secher 1991).

Septoria tritici has been the dominating Septoria disease since the beginning of the eighties and, therefore the trial results have mainly been based on this disease.

In order to find the dose response for fungicides on Septoria spp field trials as well as semi-field trials have been carried out by the Research Centre for Plant Protection. Timing is another important factor which has been included in the trials in order to be able to give an optimal recommendation for control. All this work has been carried out in order to minimize pesticide input without adding to the farmers' risk of economical loss because of diseases. The results are implemented in the computer based program "PC-Plant Protection" (Secher, 1991).

MATERIALS AND METHODS

Field trials

Trials carried out in winter wheat are placed in farmers field and at experimental stations. The experimental design was a randomized complete block with four replicates and a plot size of 15 to 30 m^2. The fungicides were applied with a knapsack sprayer at low pressure (3 bar), flat fan nozzles (Hardi 4110-12) and 300 l/ha.

The trials were treated according to the different trial plans (tables 1, 2 and 3).

Table 1. The tested ergosterol inhibitors given by their commercial or code number name and active ingredients. The products are applied twice per season g.s. 30 & 45-57.

Product	Active ingredients	g.a.i./kg or l	g.a.i. per ha
0.5 l Bayfidan	triadimenole	250	125
0.5 l Tilt 250 C	propiconazole	250	125
0.25 l Alto 24 SL	cyproconazole	240	60
1.0 l Folicur 250 EW	tebuconazole	250	250
0.8 l DPX H 6573	flusilazol	250	200
1.0 l Sportak 45 ec	prochloraz	450	450
1.0 l Corbel	fenpropimorph	750	750
1.0 l Tilt top	propiconazole + fenpropimorph	125 + 375	125 + 375
1.0 l Matador	tebuconazole + triadimenol	250 + 125	250 + 250

Table 2. Trial plan for broad spectrum fungicides used at different dosages and strategies. 1.0 N of broad spectrum fungicides = 1.0 l Tilt top (125 g propicinazole + 375 g fenpropimorph), 1.0 l Matador (250 g tebuconazole + 125 g triadimenol), 1.0 l DPX N 7876 (160 g flusilazol + 375 g fenpropimorph).

Time of application					
g.s. 29	g.s. 30-31	g.s. 37	g.s. 49	g.s. 59	g.s. 69
Untreated	-	-	-	-	-
-	1.0	-	1.0	-	
-	0.5	-	0.5	-	
-	0.25	-	0.25	-	
-	0.15	-	0.15	-	
0.5	-	0.5	-	0.5	-
0.33	-	0.33	-	0.33	-
0.15	-	0.15	-	0.15	-
0.5	-	0.5	0.5	-	0.5
0.25	-	0.25	0.25	-	0.25

Table 3. Trial plans using the computer based model "PC-Plant Protection" and different timing for control of Septoria spp. The product used is Tilt top, application is carried out using 3 weeks intervals.

Time of application			
g.s. 29	g.s. 31	g.s. 37	g.s. 59
Untreated	-	-	-
0.3 l	0.3 l	0.3 l	0.3 l
-	0.3 l	0.3 l	0.3 l
-	-	0.3 l	0.3 l
-	-	-	0.3 l
0.3 l	0.3 l	0.3 l	-
0.3 l	0.3 l	-	-

"PC-Plant Protection" - computer model.

Disease assessment was carried out as per cent coverage of all green leaves by the individual diseases. Powdery mildew (*Erysiphe graminis*), yellow rust (*Puccinia striiformis*), Septoria spp. and brown rust (*Puccinia recondita*) were assessed in the trials.

Assessments were carried out with approximately 10 days intervals, starting at first application and finishing at senescence.

The plots were harvested by a plot combiner and grain yields were corrected to 15% moisture content. Thousand grain weight was measured for each plot.

Semi-field trials

Spring wheat (variety Dragon) was grown in 8 liter plastic pots out doors. At g.s. 30-31 the plants were inoculated with *Septoria tritici* or *Septoria nodorum*. The pots were covered with polyethylene for 3 days to maintain constant high humidity. For both diseases, a pycnospore suspension of 2 x 10^6 spore/ml was used. Each pot was inoculated by atomising 12 ml suspension.

One experiment was carried out with *Septoria tritici*, where the latent period was 22 days (average day temperature being 5-10°C). Two experiments were carried out using *Septoria nodorum*. The latent period was 14 days (average day temperature 5-10°C) and 8 days (average day temperature being 8-10°C) respectively.

The pots were sprayed with a knapsack sprayer using 300 l/ha and flat fan nozzles (4110-12). Table 4 gives the spraying dates relative to inoculation. The pots were assessed on all the green parts which had been inoculated with the diseases.

Table 4. Plan for semi-field trials using tebuconazole (Folicur) for preventive and curative control of Septoria spp.

Disease	Days of application relative to inoculation						Symptom appearance
Septoria tritici	-	- 3	0	+ 15	+ 10	+ 15	+ 22
Septoria nodorum I	- 6	- 3	0	+ 3	-	-	+ 14
Septoria nodorum II	-	- 3	0	+ 4	-	-	+ 8

RESULTS

Field trials

Results from the 3 different trial series are shown in fig. 1, fig. 2 and fig. 3.

Trial serie 1 shows the different efficacy of tested ergosterol inhibiting fungicides on Septoria spp. in 1990 and 1991.

The best of the products have been used for further testing, which deals with optimal timing and different dosages (trial plan 2 and 3).

Different control strategies gave acceptable control without any yield loss. A clear dose response can be seen for both 2, 3 and 4 applications per season as an average of 6 trials in 1991 (fig. 2).

Dosages less than 0.33 l/ha gave unacceptable control when using 2 or 3 applications per season. Four applications of 0.25 l/ha gave acceptable control.

When using different times of application (fig. 3), it can as an average of 6 trials be seen that a single, late application (g.s. 59) using 0.3 l/haor 2 early applications (g.s. 29 & 31) gave insufficient control. The application at g.s. 37, which happens to be just before a rainy period (see fig. 4), was very important for a good control. In one trial, assessment was carried out on flag leaf and 2nd leaf. This data show more specificly how certain strategies lack effect at different leaf levels (fig. 5). The computer model "PC-Plant Protection" had a very good effect on Septoria spp. using appropriate dose and timing. In average of the 14 trials "PC-Plant Protection" used a total of 0.8 l/ha of fungicide and 2.3 treatments in the season.

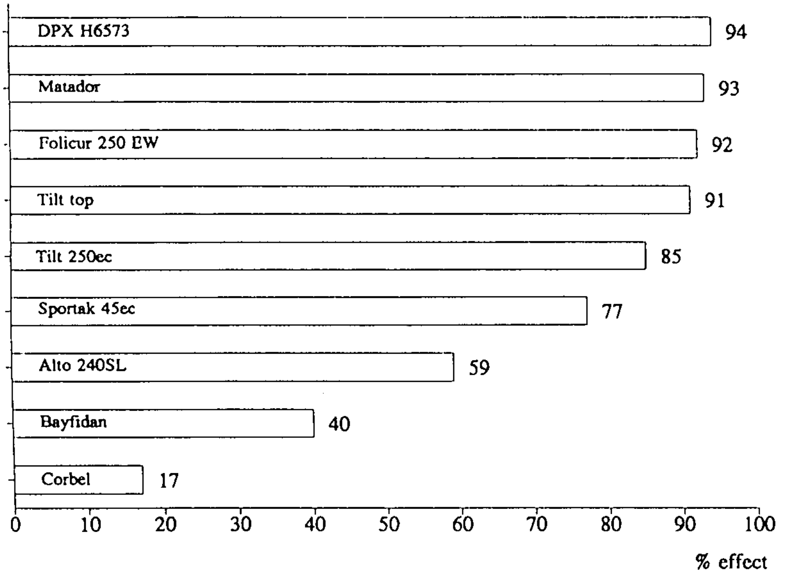

Fig.1. Per cent control of Septoria spp. in winter wheat using different ergosterol inhibitors. Average of 8 trials in 1990 and 1991. Application is carried out at g.s. 30 & 45-57. Assessment is done 30 days after 2nd application, and untreated had on average 22% attack.

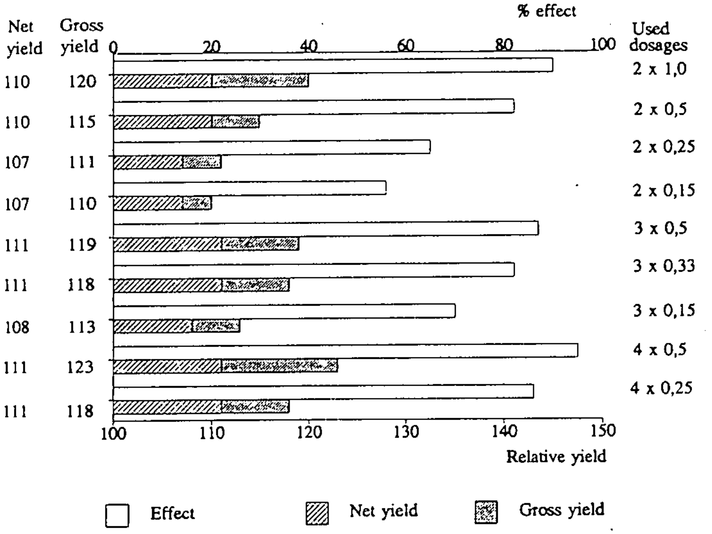

Fig. 2. Per cent control of Septoria spp. in winter wheat using different dosages and timing. Average of 6 trials in 1991 using broad spectrum fungicides (Matador, Tilt top, DPX N 7876). Assessment is done at g.s. 75. Untreated had on average 33.9% attack. Net yield is found after the cost of chemical and application has been deducted. Gross yield in untreated was 68.4 hkg/ha.

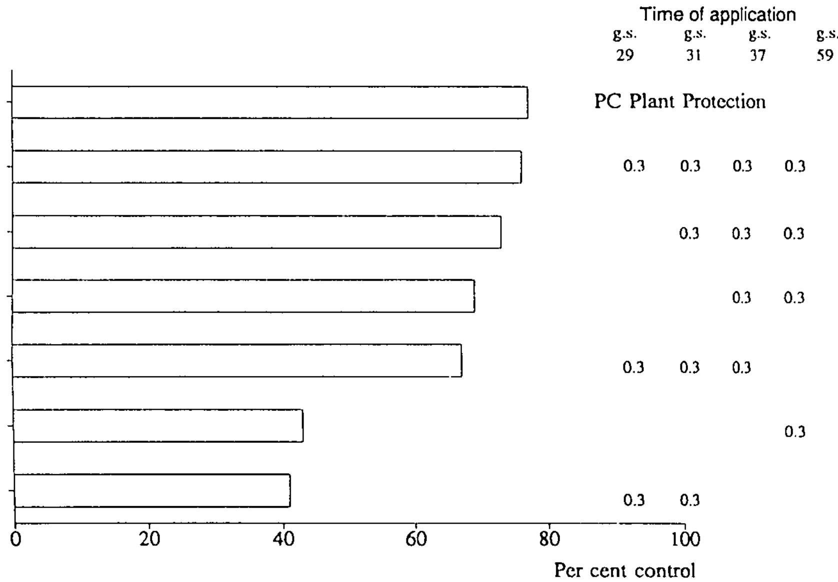

Fig. 3. Per cent control of Septoria spp. in winter wheat using different timing and the computer model "PC-Plant Protection". All applications were done using Tilt top. Average of 6 trials. Assessment at g.s. 75, where untreated had 22% attack.

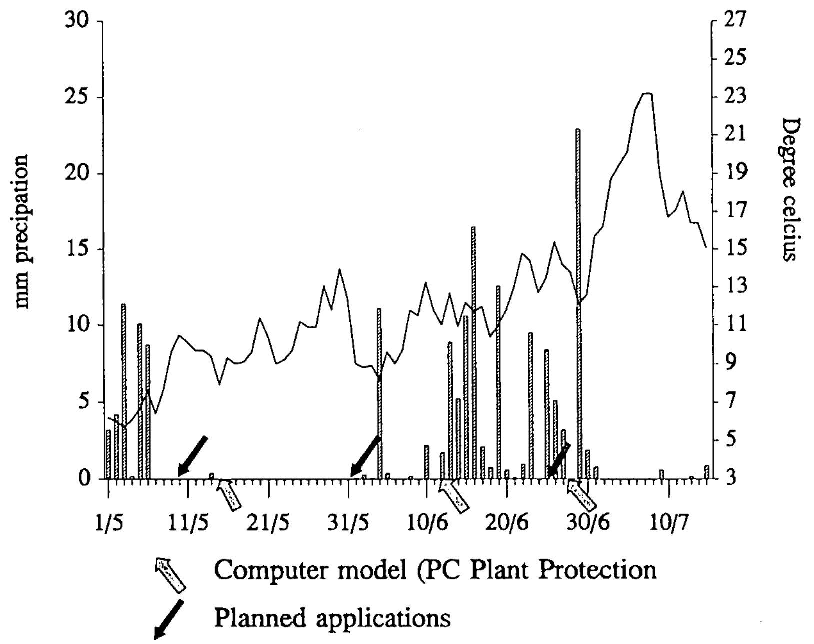

Fig. 4. Daily precipitation at Roskilde and average day temperature. Arrows indicate spraying dates. 1st application 19.04 (g.s. 29), 2nd application 10.05 (g.s. 31), 3rd application 31.05 (g.s. 37) and 4th application 25.06 (g.s. 59).

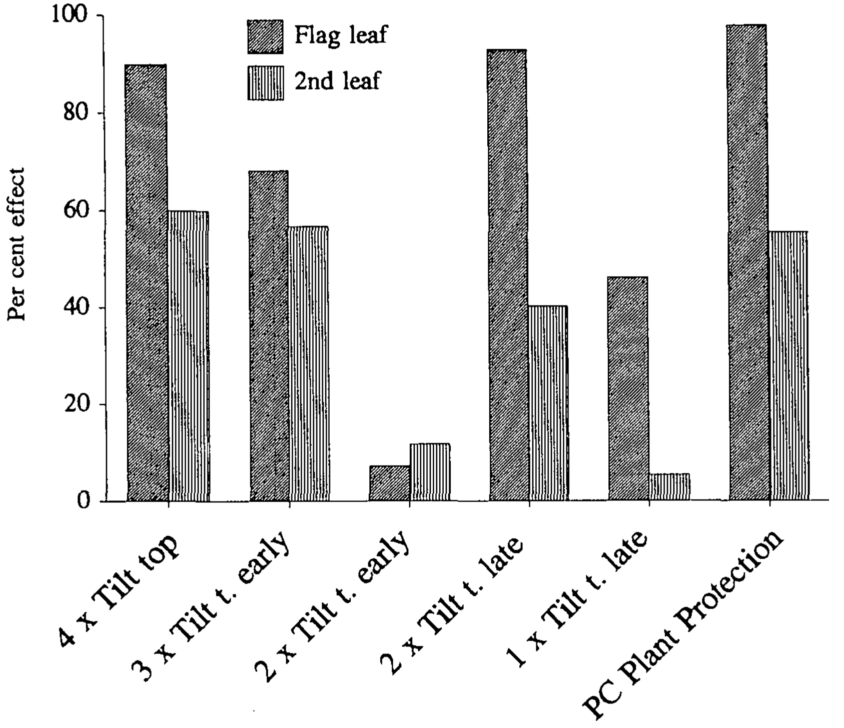

Fig. 5. Per cent control of Septoria spp. on flag leaf and 2nd leaf. Assessed an 20th July. In untreated, flag leaf had 6.9% attack and 2nd leaf had 57.8% attack.

Semi-field trials

A difference in dose response was seen on *Septoria tritici* and *Septoria nodorum* when using different times of application in relation to the time of inoculation (table 5). No dose response was found for *Septoria tritici* around the time of inoculation (day 0). 7 days before symptom appearance (day + 15), the dose response was clear, and in particular 1/4 of normal dose gave insufficient control. Application prior to inoculation gave also less effect when using this very reduced rate (day - 3).

Septoria nodorum showed some dose response at application 6 and 3 days prior to inoculation (table 6). Best effect was found when application was done just prior to inoculation (day 0). In the experiment where the latent period was 14 days full control with all dosages was seen 3 days after application. In the other experiment, which had a latent period of 8 days, the application 4 days after inoculation gave a clear dose response.

Table 5. Leaf areas (%) with symptoms of *Septoria tritici* in response to tebuconazole (Folicur) applied at various dosages and times relative to inoculation (22 day latent period).

Dose	Per cent diseased area. Days of application before and after inoculation.					Average dose
	- 3	0	+ 5	+ 10	+ 15	
1/1	4.4	0	0	0.1	2.5	0.8 A
1/2	4.4	0	0	1.9	3.4	1.4 B
1/4	10.5	0.1	0	4.4	8.0	2.6 C
Untreated	14.6					
Average timing	6.0 A	0 B	0 B	1.6 C	4.2 D	

Values with the same letter do not differ significantly ($P \leq 0.05$).

Table 6. Leaf areas (%) with symptoms of *Septoria nodorum* in response to Folicur applied at various dosages and times relative to inoculation (8 days and 14 days latent period).

1st experiment (14 days latent period).

Dose	- 6	- 3	0	+ 3	Average dose
1/1 N	1.5	0.4	0.1	0.4	0.5 A
1/2 N	2.8	1.8	0.1	0.4	1.0 B
1/4 N	4.4	5.0	0.3	0.6	1.9 C
Untreated	9.4	-	-	-	
Average timing	2.7 A	1.9 B	0.2 C	0.4 D	

2nd experiment (8 days latent period).

Dose	- 3	0	+ 4	Average dose
1/1 N	0.2	0.0	1.4	0.4 A
1/2 N	0.3	0.4	2.4	0.8 B
1/4 N	1.5	1.1	5.6	2.3 C
Untreated	13.7			
Average timing	0.6 A	0.5 A	2.8 B	

Values with the same letter do not differ significantly ($P \leq 0.05$).

DISCUSSION AND CONCLUSION

1991 was a year which gave considerable attack of Septoria spp. in winter wheat fields and good possibilities of evaluating different strategies for control of Septoria spp. were given. In particular *Septoria tritici* was dominating like it has been since the beginning of the eighties.

Several fungicides with good effect on Septoria spp. have been found from testing different ergosterol biosyntesis inhibitors (EBI). Flusilazol, tebuconazole, propiconazole, prochloraz or mixtures where these are included gave best effect. In Denmark, only propiconazole and prochloraz are registered for use at present and, therefore, these active ingredients or mixtures which contain them are used.

The difference which was seen between prochloraz and propiconazole 30 days after application correspond with the general trend indicating that propiconazole has a longer lasting effect than prochloraz. (Fehrmann & Ahrens, 1984, Obst & Huber, 1988).

The trials using different dosages at 2, 3 or 4 applications per season showed that acceptable effect on Septoria spp. was obtained using different combinations of reduced dosages in 1991. When using 2 applications with dosages less than 0.5 l/ha, the effect was unacceptable and so were dosages less than 0.33 using 3 applications per season (fig. 2). In the rainy season 1987 it was found that 2 applications at dosages less than 0.8 l/ha gave unacceptable control, (Jørgensen & Nielsen, 1988). However, in more dry seasons like 1988, acceptable control of Septoria spp. was obtained by only using 2 application of 0.3 l/ha (Jørgensen & Nielsen, 190).89

If using very reduced dosages (0.3 l/ha) for Septoria control in rainy seasons, two applications in the period from g.s. 32 to 72 are necessary in order to obtain sufficient control (fig. 3). If only 1 application is carried out in this period the dose should not be reduced more than to 3/4 of the normal dose and the application should be carried out after g.s. 45. One application using 0.3 l/ha at g.s. 59 gave insufficient control (fig. 3). This was also the case using 2 early applications of 0.3 l/ha at g.s. 29 and 31, which indicates that it is not possible to eradicate the disease at earlier applications. It has been seen that small amount of disease left after treatments will give sufficient attack to continue the epidemic in rainy seasons.

In the semi-field trials where the preventive and curative effect on *Septoria tritici* and *Septoria nodorum* was measured for tebuconazole, it was found that good effect could be obtained, however, reduced dosages decreased the period in which optimal control could be reached.

Several other experiments using EBI fungicides have shown good protective effect on *Septoria nodorum*. For difenoconazole, 14 days preventive effect was found (Mittermeier & Dahmen, 1989). Also cyproconazole and prochloraz gave good preventive effect (tested up to 12 days before inoculation), although high dosages were necessary the longer the time period between application and inoculation (Staehle-Csech et al, 1989).

Good curative effect has been found for tebuconazole, prochloraz and other fungicides on *Septoria nodorum* (60% effect) when application took place 7 days after inoculation (latent period of 6 days) (Eynard & Shephard, 1990). Similar results have been found by Verreet & Hoffmann (1986).

For *Septoria tritici* has been found a protective effect up to 28 days after application with EBI fungicides. This has been the case for leaves which have been treated, but does not include new leaves (Jordan et al, 1986).

Good curative effect on *Septoria tritici* has been found for several EBI fungicides. With a latent period of 13 days, good curative effect (90%) was found up to 8 days after inoculation (Eynard & Shephard, 1990). In experiments with a latent period of 42 days, full control was obtained by prochloraz and flutriafol + captafol 28 days after inoculation even up to 35 days after inoculation prochloraz still gave good control (Jordan et al, 1986).

Pycnidial development was inhibited by application after the appearence of leaf symptoms. Even after the appearance of pycnidia, EBI fungicides had a reducing effect on sporulation (Eynard & Shephard, 1990).

The Danish semi-field results confirm that the EBI products give good protective as well as curative effect on Septoria spp. diseases. Also the use of reduced dosages is possible, although the period of optimal and safe effect is reduced.

A conclusion from trial work with Septoria spp. over the years has been that the dosages used for the model should not be reduced more than approximately 50% per treatment in order not to bring the farmer into a too high risk situation. Further reduction is possible, but only when a better basis for risk assessment in the computer model has been defined.

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PHENOLOGICAL SIMULATION MODELS AND PESTICIDE APPLICATION TIMING

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ABSTRACT

Some practical aspects of use of phenological simulation models as a decision tool are discussed with an example of *Lobesia botrana* the grape berry moth. The relation between the efficiency of a treatment and its application time is studied by simulating the action of 3 types of insecticide which are representative of what is used in the filed. Errors in forecasting due to the use of historical weather data such as average daily temperature over 20 years are also discussed. This is used to look at the needed precision level of a model for being useful as a decision tool. It seems that even a model with poor precision of 7 days error can bring some interesting information in a frame work of decision support system.

KEY WORDS: phenology, treatment - timing, simulation, pesticide, monitoring

INTRODUCTION

Insect phenological models are largely proposed as a component of IPM (Integrated Pest Management) systems. The methodology to build them, and theoretical aspects are very well documented (Hudes & Shoemaker 1988; Logan 1988). Monitoring, sampling or treatment timing are some of proposed application areas for such a models. Among these the last one seems to interest people working on computerized decision tools (Croft & Welch 1984).

Our purpose is to study some practical aspects of this special use of phenological models. These are the needed precision of a model, its forecasting potential and the possibility of its adaptation by different users.

The problem of precision seems to us very important. It seems that some models in spite of their poor precision can bring us some supplementary useful information. Croft at al. (1981) have pointed that some models which are not acceptable from the research point of view could be useful for a practical purpose.

It is obvious that the accepted level of precision of a model varies according to the situation in which it is going to be used. Many factors would interfere: number of treatments, the residual effectiveness of the pesticide etc.

Insecticides are often proposed for only some specific stages of the life cycle (egg, larvae, pupae and adult). Within this (these) stage(s) there may be an age limit for effectiveness of a pesticide. An ovicide, for example may destroy only the freshly laid eggs.

A good timing for a treatment imply that the pesticide will reach a big numbers of pest population. This means that at treatment time, a large proportion of pest population must be in that particular stage which is sensitive to the pesticide. A good phenological model can show, at every moment, what proportion of an insect population has reached a given developmental stage. Using this information given by the model, one can decide about the application time of a given pesticide.

This study concern the grape berry moth *Lobesia botrana* (Den. and Schiff) (Lepidoptera : Tortricidae) a very important pest of vineyards in France whose biology is studied by Bovey (1961). The overwintering pupa gives rise to the adult in spring and according to the region there may be from 2 to 3 generation in summer. There exist a variety of chemical or biological treatments against Lobesia.

MATERIALS AND METHODS

A phenological simulation model of *L. botrana* (Baumgartner and Baroni 1988) is used in this study. This model has been validated with pheromone trap and field count data from a vineyard in Provence in France (Mayer & Reynaud 1991 unpublished).

We simulated the action of an insecticide applied at different moment and compared their efficiency. The treatment efficiency is calculated by the percentage of population reached by the pesticide. This simulation study allows us to determine the best treatment time and the rate of efficiency reduction due to a deviation from the optimum application time.

Three hypothetical types of insecticide are used in our simulations (Table 1). These could be considered as the representative of some commercialized products. The effect of each of them is studied independently in first and second generation.

Table 1. Characteristics of products used in simulations.

Treatment type	Target population	% of mortality	Residual effectiveness
I	1 dag old eggs	90%	constant during 14 days
II	Young larvae (L1 to L2)	90%	linearly decreasing during 20 days
III	Eggs	90%	1 day
	Larvae (L1 to L5)	90%	decreasing to 50% in 5 days

The application time producing a maximum efficiency (percentage of mortality among the target population) is considered to be the optimal timing. This maximum efficiency is compared to those obtained by treatments applied a week later or sooner than the optimal timing.

We have used the average daily temperature over 20 years to forecast the development of the population for the forecoming two weeks. This kind of forecasting has to be done in the framework of a decision making tool. The most cold and hot observed years over this period are used to simulate the most and the least rapid possible development of the pest population.

The effect of a permanent increase or decrease of some degrees on the result of simulation is studied to see how the model is sensitive to the precision of temperature measurements. This seems to us very important when considering the problem of adaptation of the model by different users.

RESULTS

The evolution of the target population of these 3 insecticide is shown in figure 1. We can see the percentage of population which are in young egg, young larvae (L1 an L2) or larval (L1 to L5) stage. The cumulated percentage of the population reached adult stage and the optimal treatment times are also shown on this figure.

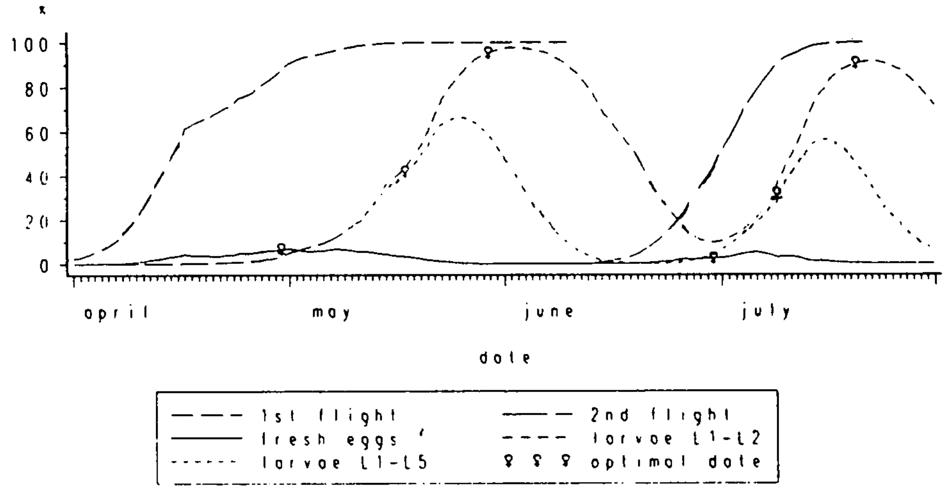

Figure 1 - Proportion of population of 3 insecticide target stages (very young eggs, young larvae and larvae) relative to the whole population and cumulated percentage of individuals reached 1st and 2nd generation of adults. The optimale application time is marked for each insecticide.

The percentage of mortality produced by a treatment applied at the optimal time and a week later or sooner is shown in table 2 . The results for first and second generation are presented separately. Table 2. Treatments efficiency depending on the time of application.

Table 2. Treatments efficiency depending on the time of application.

Treament		I	II	III
Target population		Eggs	Larvae L1-L2	Eggs & larvae
First generation	A week sooner	33	80	95
	Optimal timing	42	93	99
	A week later	38	82	96
Second generation	A week sooner	38	73	85
	Optimal timing	55	88	95
	A week later	36	73	88

In first generation a treatment applied a week later or sooner than the optimal date doesn't produce more than 20 percent reduction of its efficiency. This will amount to 35 percent for the second generation. The difference can be explained by the fact that second generation is spread over a shorter period of time and consequently is more sensitive to a deviation from an optimal timing.

On the other hand it seems that the optimal treatment time is more important when the target stage duration is shorter. In our simulation studies we used 3 type of pesticide. The first one eliminates only the very freshly laid eggs (a one day stage), the second one acts on young larvae (about 5 days stage) and finally the last one which suppress all kinds of larvae (20 days stage). The effect of a deviation from an optimal treatment time is more important for the first type of treatment that for the second type.

The table 3 shows the error due to the forecasting of the development of the pest population using the average daily temperature over 25 years for about 10 days. A phenological event (10% of total eggs already laid or 10% of all eggs already hatched) is predicted using the observed daily temperature of a normal, a very cold and a very hot year (cheesed over 25 years). The delay forecasted by the average temperatures is almost the same as the one obtained by the real temperature of 1991 summer. However from a practical point of view one has to consider that this delay would be somewhere between the two extremes. This means that the computer program find that 10% of total eggs would be laid within a delay of 8 to 14 days where actually this delay is 10 days.

Table 3. Forecasting error due to the use of average daily temperature.

Phenological event	Delay predicted by model using daily temperature of			
	1991	a cold year	a normal year	a hot year
10% of total eggs laid	10	8	10	14
10% of total eggs hatched	7	6	6	9

Table 4 shows the effect of addition or subtraction of one or half a degree to (or from) the daily temperature on the simulation results. Although it can produce an important shift of predicted time of an event (50 % adult flight for example) in first generation, no significant effect is seen for the next generation. The reason is that in spring, during the development of first generation, temperatures neighboring the developmental thermal threshold are frequent. Therefor even a very small change of temperature may produce a considerable change of simulated results.

Table 4 - Sensitivity of model to temperature measurement accuracy.

Daily temperature change	Delay produced in predicting 50% of acult flight	
	First generation	Second generation
- 1.0	16	2
0.5	9	1
+ 0.5	4	1
+ 1.0	8	1

DISCUSSION

In the absence of any phenological models information available for pesticide application timing comes from pest monitoring. This would be vary time consuming if it was to cover the whole life cycle of the pest. The monitoring of adult flight with pheromone traps is often the only source of information about the development of population pest. So from decision - making point of view the usefulness of a model is not to be judged according to its precision but by the supplementary information produced by it.

The adult flight monitoring gives us some approximate indications about the beginning, the middle and the end of the flight. Each of these could be spread over a period of one week or more. The first adult captured in a pheromone trap doesn't mean the real beginning of the adult flight as a population phenomena. One can consider that the real beginning of the flight is when , for some consecutive days, there are some adults captured in the trap. The middle of the flight curve is also difficult to determine. In practice when the number of captured males becomes important one can decide that the middle flight is attained. This can happen over a period of 2 weeks. Finally the end of the flight cannot be known neither. Sometime there is a confusion about the beginning of the second generation and the end of the first generation. So in practice we consider that we are at the end of the flight when the number of adults captured in the trap is reduced a lot. So for the adult flight which last about 6 weeks in first generation and 4 weeks in second one we are far from having a precision of one week for any kind of phenological events.

What would be the real condition of use of a phenological model?. Based on daily temperature the model gives the proportion of population passing through different stages of the life cycle. This information could be insufficient to decide about the application time. We don't know what would be the evolution of the situation in the future (depending on weather) and on the other hand we may need some preparatory delay time for some treatments. For this reason the model has to forecast the future development of the pest population using the historical weather data. We can use this information to choose the application time where a large part of pest population is passing through the target stage of that treatment. Although this is not the optimal application time (which can be determined only a posteriori), it wouldn't be very far from it. The difference between them depends on the inherent precision of the model and the error due to the forecast.

As we have seen in table 2 even a model giving an optimal treatment time with 7 days error can still be of great help. In first generation the efficiency is never reduced more than 20 % . This is also true for second generation with the exception of very specific treatment where a very short part of the life cycle is the target of the treatment. When looking at figure 1 we notice that it is very hard to interpret the adult flight (the only information available in absence of any model) in terms of life cycle of pest population. So we can consider that even with a poor precision a phenological simulation can take part in a decision support system.

We must not forget that in practice the error produced by the model will add to error due to forecasting. This means that a model which simulate a phenological event with a 7 days error can end up with a forecast of 2 weeks error due to the use of historical weather data. The danger of such a situation can be reduced by using the results of adult flight monitoring to rectify the simulation results regularly.

The last point concern the adaptation of such models by different users. As we mentioned earlier, in first generation, daily addition or subtraction of even half a degree can produce an important shift in simulated results. From the practical point of view this imply that the model is very sensitive to temperature measuring instruments. This means that each user has to calibrate the model to its own conditions before its real use as a decision tool.

The general framework of this study is the integrated pest management where it is important to reduce the number of treatment application.. We tried to show how a phenological simulation model can be useful as a decision tool. We studied the cases where each type of pesticide is applied only one time during each generation. The situation will be different if one decide to apply a treatment many times during one generation. In this case the beginning of the adult flight is the most important information needed to obtain a complete pesticide coverage.

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WORKSHOP ON COMPUTER-BASED PLANT PROTECTION ADVISORY SYSTEMS
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COMPUTER-BASED METHOD OF FORECASTING SCLEROTINIA STEM ROT ON SPRING SOWN OILSEED CROPS IN SWEDEN

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ABSTRACT

Sclerotinia sclerotiorum is a major disease on spring sown oilseed crops in central Sweden. 60-70% of the total oilseed crop is springsown in Sweden and therefore S. sclerotiorum is of great economic importance. In some years e. g. 1984, 1987 and 1991 there have been serious infections causing great crop losses. Investigations on Sclerotinia stem rot have been carried out during the last decade to develop a method of forecasting disease incidence. Relationships between climatic factors, as well as field specific factors, and disease incidence on spring sown oilseed crops have been studied during the last 7 years. Risk assessment based upon these factors has been tested. Close correlations between predicted actual values and incidence of the disease have been observed.

INTRODUCTION

In Sweden oilseed crops have been of great importance during more than 40 years. The total area planted during the last 10 years has been about 160.000 ha per year. Of these about 110.000 ha are spring rape (Brassica napus) and spring turnip rape (Brassica campestris). Most of the spring sown rapeseed crops are grown in central Sweden, while about 80% of the wintersown oilseed crops are grown in southern Sweden.

Sclerotinia stem rot, caused by Sclerotinia sclerotiorum, has become a serious problem in areas with intensive growing of oilseed crops in central Sweden. Yield reductions of 30-50% have been observed in fields with heavy attacks by Sclerotinia stem rot

During the last decade surveys have been carried out especially in central Sweden to obtain information about the annual incidence of Sclerotinia stem rot and to estimate the economic importance of the disease. Each year about 150 fields have been surveyed and usually 200 plants per field have been inspected.

A number of field-specific data have also been collected e. g. crop rotation, sowing date, flowering period, crop density, use of fertilizer, irrigation, disease incidence, number of sclerotia developed in diseased plants and use of chemicals. Weather data have also been collected from different locations e. g. amount of rain.

In 1984, 1987 and 1991 disease incidence of Sclerotinia stem rot was very serious in many fields in central Sweden. In 40-50% of inspected fields more than 20% of the stems were attacked by Sclerotinia stem rot. Yield reduction could be estimated to more than 30% in 20-30% of the fields.

COMPUTER-BASED METHOD OF FORECASTING SCLEROTINIA SCLEROTIORUM

Since 1987 a method of risk assessment has been tested to forecast the incidence by Sclerotinia stem rot. The method is based upon a number of field-specific data such as crop rotation, crop density, amount of inoculum in the soil, flowering period and amount of rain during spring and early summer. Data on apothecia formation and the amount of rain and weather forecasts from each region are also included in the risk assessment.

A computer-program was developed for calculation of risk assessment based upon a risk value for each factor. From a weather data-base it was possible to get actual data on rainfall during spring and early summer from 50-60 locations in Sweden. The weather data-base was up-dated each day automatically from the Swedish Meteorological Institute to a Wax- computor at the Swedish University of Agricultural Sciences. These weather data could be directly incorporated in the calculations.

The method has been tested during the last 5 years. There is a good agreement between forecasted values on disease incidence in each field and observed results.

Table 1. Risk assessment of Sclerotinia stem rot in spring sown rape seed crops in central Sweden 1987-1990.

Risk points	No. fields tested	% stems attacked by S. sclerotiorum, average
0-20	0	0.1
21-40	56	0.9
41-60	76	5.1
61-80	60	4.8
81-100	21	14.9
101-120	26	27.0
121-140	17	43
140-	5	38

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FORECASTING POTATO VIRUS Y - A SIMULATION MODEL

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ABSTRACT

Potato virus Y and many other viruses of potatoes cause great economic losses to seed potato production in many countries. During the last decade there has been an increasing interest in developing methods for potato virus forecasting. In Sweden the relationship between occurence of alate aphids and the proportion of PVY infected progeny tubers has been studied since 1975. A dynamic simulation model for PVY has been designed for predicting the incidence of PVY. The simulation model describes a system which includes e. g; healthy and PVY diseased potato plants, different aphid species as virus vectors an their efficiency as virus vectors, the susceptibility of the potato crop according to mature plant resistance and date of haulm destruction. There was a good correlation between model output and samples of progeny tubers tested for PVY.

INTRODUCTION

In Sweden and in many other countries in northern Europe, PVY is one of the most important virus diseases of potatoes. Its incidence is generally much higher than that of potato leafroll virus (PLRV), probably because the main vector of the latter, *Myzus persicae*, is much less abundant in potato fields compared with other aphid species which can transmit PVY but not PLRV (Sigvald, 1990).

Although the spread of PVY^0 in Sweden is negligible during most years, outbreaks of this virus have been recorded on a few occasions since 1970, especially in southern and central regions (Sigvald, 1987). In the northern regions of Sweden, which are important areas for seed potato production, the incidence of PVY^0 has been very low, mostly because few vectors and few virus sources are present in the fields (Sigvald, 1987).Although PVY can be transmitted by aphid species that feed preferentially on potatoes, other species that do not colonize potatoes seem to be more important, e.g *Rhopalosiphum padi, Brachycaudus helichrysi, Acyrthosiphon pisum and Phorodon humuli* (Edwards, 1963, van Hoof, 1980; Kostiw, 1980; Sigvald, 1984).

The relationship between aphid migration and the spread of PVY has been studied by exposing bait plants to vectors in the field (de Bokx, 1979; Ryden et al, 1983; Sigvald, 1989). Winged aphids have also been collected and placed on test plants to determine whether or not they are viruliferous (de Bokx and Piron, 1984, 1985, 1990; Harrington, et al, 1986; van Hoof, 1980). There are great differences in virustransmission efficiency between aphid species (de Bokx and Piron, 1990; Harrington and Gibson, 1989; Katis and Gibson, 1985; Sigvald 1984).

During the last decade there has been increasing interest in developing methods for PVY forecasting. The main variables used when forecasting the incidence of PVY include the number of winged aphids and their efficiency as vectors, the time of aphid migration in relation to plant age and the availability of virus sources (van Harten, 1983; Sigvald, 1985, 1986).

Simulation models have also been used to describe the epidemiology of non-persistently transmitted viruses (Ruesink and Irwin, 1986; Sigvald 1986).In this paper the epidemiology of PVY is described in a simulation model for predicting conditions in potato fields in Sweden.

EPIDEMIOLOGY STUDIES OF POTATO VIRUS Y IN SWEDEN

During the last 15 years epidemiology studies was carried out in Sweden both in field experiments and laboratory studies. The flight activity of winged aphids was monitored by using yellow water traps (YWT) and suction traps. Aphids were collected three times a week, and eight species were identified: *A. pisum, Aphis fabae gr., Aphis nasturtii* and *Aphis frangulae together, Brevicoryne brassicae, Metopolophium dirhodum, M. persicae, R. padi,* and *Sitobion avenae.* All other species were assigned to a category " Other aphid species". There were a great difference in aphid flights between years and regions (Sigvald, 1987).

Virus translocation in potato plants and mature plant resistance have been studied in several countries (Beemster, 1987; Gibson, 1991; Sigvald, 1985). The different studies show clearly that mature plant resistance to PVY is important when determining the risk of virus spread. Field experiments carried out in southern Sweden showed that mature plant resistance increased markedly during July, the main period of aphid fligt in Sweden (Sigvald, 1985).

Aphid species transmit PVY with different efficiencies, and laboratory experiments indicate that *M. persicae, Myzus certus, A. nasturtii, Brachycaudus helichrysi, A. pisum and Phorodon humuli* are efficient, while *R. padi, S. avenae, A. fabae and M. dirhodum* are less so (de Bokx and Piron, 1990; van Hoof, 1980; Kostiw, 1980; Sigvald, 1984). However, results differ greatly, owing in part to differences in methods, test plants, and aphid biotypes.

In Sweden (Sigvald, 1984), in Netherlands (de Bokx and Piron, 1990) and in England (Harrington et al.,) relative efficiency factors have been assigned to various aphid species. There are differences between the different studies, which partly could be explained by differences in methods (de Bokx and Piron, 1990).

SIMULATION MODEL FOR PVY

Results from field experiments, laboratory studies and the literature were used to develop the simulation model for PVY^0 spread. Data were also collected from a number of potato fields in southern and central Sweden, from 1982 to 1985, to evaluate and verify the model.

The data collected at each field were generally as follows: cultivar, planting date, proportion of diseased plants serving as virus sources (field inspection), date of emergence, date of flowering, date of progeny tuber formation, date of removal of PVY^o diseased potato plants and number removed per ha, use of mineral oil, irrigation and date of haulm destruction. From each field samples of 300 progeny tubers were collected after harwesting and tested for PVY (glasshouse test).

The goal has been to develop a dynamic simulation model for PVY that describes relationship between important variables an parameters and gives a good overview of the epidemiology of PVY^0.

Some of the most important variables and parameters are:

1. Healthy potato plants.

2. Newly PVY^0 infected potato plants not yet acting as virus sources.

3. Totally PVY^0 infected potato plants acting as virus sources.

4. Spread of PVY.
This rate variable is proportional to the infection risk, and is influenced by the degree of mature plant resistance, vector efficiency, cultivar-related susceptibility

5. Infection risk.
The risk of healthy potato plants to become infected with PVY is calculated by multiplying the proportion of healthy potato plants by the proportion of PVY diseased potato plants acting as virus sources. The effect of multiple infection is taken into account (Gregory, 1948)

6. Latent period.

7. Mature plant resistance.
Mature plant resistance increases with the age of the inoculated plant (Sigvald, 1985). From emergence until day 25 a susceptibility factor of 1.0 is used; the factors used during succesive weeks thereafter are 0.8, 0.6, 0.4, 0.2, 0.1, and 0.0.

8. Vector efficiency (Table 1).

Because YWT are species selective, the flight activity of some aphid species, e. g. will have been underestimated. Therefore, the efficiency factor for *R. padi* is higher than results from different experiments indicate.

9. Date of haulm destruction.

10. Proportion of progeny tubers infected with PVY.

11. Cultivar susceptibility.
Potato cultivars differ in susceptibility and are thus assigned different susceptibility factors: the greater the susceptibility, the higher the factor value, which ranges from 1.4 to 0.6.

12. Removal of PVY-diseased potato plants.
The risk for spread of PVY^O can be decreased by removing PVY^O-diseased potato plants from the field before the main aphid flight.

Table 1. PVY^0 vector efficiency factors for 8 aphid species and a group of other less common aphids. The factors are used in the simulation model.

Aphid species	Efficiency factor
Myzus persicae	1,0
Acyrthosiphon pisum	0,7
Aphis nasturtii, A.frangulae	0,4
Rhopalosiphum padi	0,4
Metopolophium dirhodum	0,3
Aphis fabae	0,1
Sitobion avenae	0,01
Brevicoryne brassicae	0,01
Other aphid species	0,2

RESULTS FROM TESTING THE SIMULATION MODEL

After constructing the relational diagram (Forrester, 1961) and writing the DYNAMO-code (Pugh, 1977), the program was run several times using a range of aphid numbers, initial proportions of potato plants infected with PVY^O, levels of mature plant resistance, latent period length, etc., to compare the general behaviour of the model with the real system. The predicted proportions of progeny tubers infected with PVY^O were compared with measure values obtained in the 1975-1977 field experiments (Sigvald,1989). There was good agreement between the model output and data from the field experiments (Sigvald, 1986).

When the aphid migration took place in July the model output correctly predicted that the proportion of progeny tubers infected with PVY^O would increase during August, about 3 weeks later. By changing the date of emergence it was also possible to compare the model output with results from field experiments (Sigvald, 1985) in which mature plant resistance had been studied.

SENSITIVITY ANALYSES

The importance of different factors within the PVY^O model was assessed by varying different variables and parameters. The magnitude of the changes was restricted to keep values within the ranges determined in the field and laboratory studies, i.e. usually no more than a 50 percent increase or decrease in most variables.

Table 2. Sensitivity analyses of the vector efficiency for the aphid species R. padi, A. fabae and M. persicae. The percentage PVY^O infected progeny tubers (forecast values) for 50% increase or decrease of the initially efficiency factors.

% PVY^O infected tubers using Table 1. eff. factors	*R. padi*		*A.fabae*		*M. persicae*	
	-50%	+50%	-50%	+50%	-50%	+50%
55,4	34,1	72,9	49,3	60,8	53,9	56,8
10,5	9,0	12,1	10,3	10,7	10,5	10,6
8,2	7,3	9,3	8,1	8,4	8,1	8,3
1,3	1,1	1,5	1,3	1,3	1,2	1,3
0,6	0,6	0,6	0,6	0,6	0,6	0,6
0,9	0,8	1,0	0,8	1,0	0,9	0,9
22.8	16,1	30,2	21,2	24,4	22,6	23,1

Most of the aphid data used were from the 1975-1977 field experiments. Changing the proportion of PVY^O-diseased plants serving as virus sources had a great influence on the proportion of potato tubers infected with PVY^O: Thus an increase in the former from 0.1% to 0.5% caused the latter to increase from 20% to 60% infected progeny tubers.

Aphid migration differs greatly between years and regions. Therefore data obtained on aphid catches in YWT from about 10 different regions and years were used in the sensitivity analyses in which vector efficiency values were varied (50% decrease or increase). Such changes had a great influence on model output for *R. padi, A. fabae* and "other aphid species", but only slightly affected the output for *M. persicae* (Table 2). These simulations indicate that early and large migration of PVY^{O} vectors are important mainly if the aphid species concerned are not very efficient as vectors of PVY^{O}, for example *R. padi*.

Data from about 70 potato fields were used for parameter estimation and for simulations. When testing the validity of the model, however, we used data from 100 other potato fields. There was a good correlation between predicted values and observed results, r^2=0.80, p<0,001 (arc sin transf,). The results are similar to those described earlier (Sigvald, 1986).

DISCUSSION

The computer-based simulation model has become an essential tool for use in analysing results from epidemiological studies. In the present study, there was a close correlation between the predicted proportion of progeny tubers infected and disease incidence estimates made in the 1975-1977 field experiments (Sigvald, 1986, 1989), indicating that the model predictions can be accurate.

Similarly, in 1976, when there was a very large aphid migration early in the summer, the model accurately predicted the proportion of progeny tubers infected with PVY^{O} in early September (measured incidence = 93%, predicted incidence = 96%). Furthermore, in 1977, when vectors populations were low, both predicted and measured values were ca 2%. Thus the model has great flexibility, providing accurate predictions under a variety of conditions.

Simulation models offer many advantages in virus epidemiology work. For example, they can be used to evaluate the relative importance of different variables. The influence of the proportion of PVY^{O} diseased potato plants serving as virus sources on the proportion of progeny tubers infected with PVY^{O} can easily be demonstrated for any given level and pattern of vector intensity.

If very young potato plants are inoculated with PVY^{O} they can act as virus sources relatively early in the season, when many alates are still migrating and thus increase the risk for PVY^{O} infection of progeny tubers. On the other hand if alates are migrating late the risk for PVY infection of progeny tubers will decrease dramatically because of greater mature plant resistance and a longer latent period. Also in this case there is good agreement between field data (Sigvald, 1985) and model output.

By taking the vector efficiency of a given aphid species into account along with the timing of its main flight period and number of individuals, the importance of the species as a PVY^{O} vector during a given year can be estimated. Thus an aphid species with a high vector efficiency that migrates early in the season, when the potato plants are very susceptible, may, nevertheless, be given a low vector-importance rating in the model if it generally migrates in low numbers, as is the case for *M. persicae*. Other studies have shown that *R. padi* can occasionally be an important vector under Swedish conditions (Sigvald 1987,1989). Hence, by running such simulations we can get a better understanding of the relative importance of different aphid species as vectors of PVY, thereby helping us in developing priorities for future research.

The effects of various cultural practices on disease incidence can easily be simulated. Removal of PVY^{O}-diseased potato plants before the main flight of the primary vectors can greatly reduce the proportion of progeny tubers infected with PVY^{O}. However, removal of diseased plants during or after the aphid flight period has little effect (Fig. 2). Early haulm destruction decreases the PVY^{O} infection risk for progeny tubers. Simulations can also predict the effect of planting sprouted seed potatoes early.

FORECASTING THE INCIDENCE OF PVY

This study shows that the PVY^{O} simulation model can be used in forecasting the risk for virus spread. In Sweden, as well as in other countries, there are great differences in virus spread between years and regions (Sigvald, 1987). In Sweden during years when the incidence of PVY is low, there is no need to test progeny tubers after the harvest. Thus by using the simulation model to forecast PVY incidence, farmers would be allowed to not test progeny tubers for PVY during low-disease years, thereby reducing their operational costs. Similarly, disease incidence can be reduced by taking prophylactic measures at an early stage. However, such measures, e.g. mineral oil application, are too expensive to used on a routine basis; thus if the risk for PVY spread could be predicted, such treatments could be used more selectively, thereby reducing costs.

The seed potato grower would also benefit by being able to predict the proportion of progeny tubers infected in late summer. If there is a great risk that the level of infection of the tuber yield will exceed the threshold set for seed potatoes, it may be more profitable to delay haulm destruction and market the potatoes for consumption or industrial use (starch or ethanol). During the last five years the forecasting method presented here has shown great promise when applied under practical conditions.

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METHODS IN PATHOGEN AND DISEASE ASSESMENT

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ABSTRACT

Pathogen and disease assesment is still at a stage in which uniformity in methodology and agreement on criteria are needed. Disease assesment, as result of the interaction between pathogen, host and environment, is particularly considered. Methods in disease severity assesment, time and frequency of assesment, sampling method and sampling size have been discussed. Related problems and possuble resolutions have been shown, taking in account that primary errors in disease assesment results in subsequent errors which cannot be corrected at a later stage.

KEY WORDS: pathogen assesment, disease assesment, assesment methods.

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PLANT AND DISEASE MODELS FOR USE IN DECISION SUPPORT PROGRAMS FOR BIOCIDE APPLICATION

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ABSTRACT

Mathematical models of crops, weeds and diseases can be used to help in making decisions about chemical applications for weed and disease control. Two weed population models are described briefly: one to assess the benefits of patch spraying, and a dynamic programme to optimise crop rotation, cultivation method and herbicide use for long-term weed control. A model of cereal and fungus development is used to compare standard strategies for fungus control, and a model-directed strategy is described which gives better results. Several possible directions for future research are discussed.

KEY WORDS: fungicides, herbicides, spraying, timing, decision modelling.

INTRODUCTION

A current research project at Silsoe Research Institute is analysing the management of chemical applications with a view to reducing farm imputs. Earlier work (England 1986) considered nitrogen fertiliser applications and current work is considering fungicides and herbicides. The work on fungicides will form the main part of this paper, but the work on herbicides will also be described briefly.

A common factor of these studies is the use of mathematical models in decision making frameworks: the work on nitrogen used linear programming, that on fungicides uses simulation and optimisation, and the work on herbicides uses a stochastic model and dynamic programming. The choices of model and decision making method are inter-related. Ideally the method would be chosen to suit the decision and the appropriate model would then be selected. In practice, the availability of models constrains the choice of method.

In many cases the biological models required for plant protection advisory systems are unavailable or inadequate. For example, the cereal disease model has only been properly validated for mildew on spring barley. Also many models that perform well against carefully conducted trials are less successful when used in practice, which damages the reputation of model-based advisory systems in general. Outside controlled trials there are many additional sources of variability which must be allowed for in constructing and using the models. Some of these issues are discussed in the last section of the paper which looks at research directions in the use of decision support systems on farms.

HERBICIDES

Long-term weed control strategies

The aim of this work is to find the optimum combination of rotation, cultivation and herbicides to control weeds in a given situation over a period of several years. The optimum is normally defined as maximum farm profit, but could be defined as minimum number of chemical applications or restrained by limits on chemical applications.

In the dynamic programming model the state of the system at any time is represented by the number of each type of weed seed and the time since the last break crop. The transitions between states are determined by the operations performed, such as ploughing, shallow cultivation or herbicide spraying. The effects of cultivations are assumed to be deterministic, but uncertainty is introduced in the form of herbicide effectiveness, which has been found to have a log normal distribution. The transitions are thus represented by matrices giving the probabilities of moving from one state to another. The effect of a series of decisions over several years can be found by multiplying the appropriate state transition matrices. The model also includes the revenue for each combination of initial state, final state and decision. This revenue may be purely financial or may also include environmental costs. The dynamic program method maximises the expected revenue over a period of several years by using a backward chaining method to select decisions at each step.

This work is still in progress so no results can yet be reported but a simplified model has been completed (Sells, 1991).

Patch Spraying

Automatic control of sprayers to deliver chemicals to particular regions of a field is an important engineering development for reducing the amount of chemicals used. A model has been constructed which simulates the development of weed patches within a field over many years. It shows that, given a uniform initial distribution and uniform conditions, weed patches develop naturally, and it allows the effectiveness of different policies for patch spraying to be compared. Table 1 shows one set of results for blackgrass using 2 threshold densities for spraying, 2 patch sizes (the minimum area that the sprayer can treat) and 2 rates of weed control. The results are expressed as the net present value including chemical costs and yield loss over 10 years compared with spraying the whole field every year. In 2 cases it is more profitable to leave the whole field unsprayed in the first year and spray it all in the subsequent years than to spray it all every year, so this is used as the basis for comparison.

Table 1 Net present value (£/ha) of patch spraying blackgrass over 10 years at annual chemical cost of £57/ha

Threshold seeds/m^2	Patch size m^2	Weed control %	Value £/ha
45	12	85	92
	47	85	4
	12	91	100*
	47	91	22*
90	12	85	23
	47	85	0
	12	91	51
	47	91	25

* Compared with the option of not spraying in year 1 as it is more profitable.

FUNGICIDE TIMING

The host crop model

The host crop model is a daily simulation of the life of a cereal plant from sowing to maturity. It uses historical daily weather data to calculate leaf areas, the dates of key growth stages, fertiliser uptake and an estimate of the final yield. A crop is represented as a constant number of uniform stems each with leaves of varying sizes. The decision to model the crop in this way was taken because it facilitates the testing of spray rules whose criteria are the observed levels of disease on specified leaves.

The model is based on the daily calculation of the potential growth of each leaf (including the stem and ear) from logistic curves. Potential growth is then adjusted by environmental factors to give actual growth. It is assumed that potential growth is reduced by the influences of plant nitrogen concentration, temperature, soil moisture and the plant's own stock of photosynthesised energy. Vernalisation, the intervals between the key growth stages, and the initiation of new leaves are all governed by a photo-thermal time clock. The daily increment to phenological time is calculated as the mean temperature above a variable base level modified by photoperiod and vernalisation factors.

The disease model

The disease chosen for the model was *E. gramminis* (cereal mildew). In spring barley crops mildew is the dominant disease - average annual yield losses over the period 1972-75 were estimated as 8.5% due to mildew compared with only 0.7% due to leaf blotch and 0.9% due to brown rust. Thus a model which explains the behaviour of mildew epidemics should be able to account for a large proportion of the foliar disease losses in barley.

Mildew is a fungal disease which survives and multiplies on green leaf tissue. Its lifecycle may be divided into six distinct stages; germination, incubation, lesion growth, spore production, spore release, and the death of airborne spores. The success of the fungus in each stage is strongly influenced by the weather, and this structure is reflected by the model which calculates daily weather effect values for each of these stages. Host resistance is also modelled since the infective efficiency of spores has been found to vary between varieties, between leaf layers, and with the age of the leaves. The model contains two effects of the disease on the host: one is the loss of energy income from photosynthesis, while the second is the premature senescence of leaves with a high level of disease cover.

Modelling fungicide sprays

Three aspects of spray application need to be considered: the timing of the spray, the distribution of spray within the canopy, and the fungitoxic efficiency of the chemical. Timing is determined by the decision rule being used. Spray penetration through increasing depths of leaf cover was modelled with an exponential function, the parameter being estimated from an analysis of deposition data published in two papers. Fungitoxic effects were modelled by removing a fixed proportion of the spores and lesions coated with spray. Healthy leaf coated with spray is regarded as having a degree of protection against new infection which decays with time, the rate being influenced by rainfall. Systemic effects are modelled as an active dose of chemical distributed evenly within the leaf. The protective effects of this dose are reduced by dilution due to leaf growth and by the deterioration of the chemical itself which is modelled by removing 5% of the active dose per day.

The whole model and its components were validated by comparison with results of trials over many years at various sites.

Spray decision rules

Four spray decision rules were tested: two insurance systems, a simple 'supervised' system and a more detailed 'managed disease control' strategy.

The four rules were:

Rule 1: **Calendar Days**. An insurance approach consisting of two sprays (15th May and 5th June) on susceptible varieties and one spray (15th May) on resistant varieties.

Rule 2: **Growth Stages.** Again an insurance approach is used. Two sprays are applied to susceptible varieties (at GS31 and GS39), and one spray to resistant varieties (GS31).

Rule 3: **Disease thresholds**. A spray is applied when mildew is first seen (exceeds 1% on any leaf) and a second spray is applied if and when the level on leaf 3 exceeds 3%. Disease information is used but host crop development is not.

Rule 4: **Managed control**. The criteria used are those set out in the ADAS managed disease control method (ADAS, 1984). Information on crop variety, crop development stage and disease progress is used.

These decision rules were applied to each of 80 simulated spring barley crops, being all combinations of 2 varieties (resistant and susceptible), two sowing dates (15th March and 15th April), near or not near winter barley, and ten consecutive years of weather data from Rothamsted (south-east England). The spray was defined as giving a 90% kill on contact with mildew and partially systemic.

Model-based decision making

The 4 decision rules described above differ in the amounts of information about the crop and the disease that they use. The amount of information can be maximised by including the model in the decision making process: the model can be used to predict the likely development of crop and disease, provided some form of weather forecast is available. For this investigation the crudest type of forecast - the long term mean - was used.

The following restrictions were placed on spray programmes:

1. Sprays were limited to 11 possible dates; these were at 7 day intervals from lst May to 7th July.
2. Sprays had to be at least 14 days apart.
3. No more than 3 sprays could be applied.

To simulate one year's decision making process, the possible spraying days were taken in sequence. On any given day the current state of the crop was calculated by running the program up to that date with the appropriate weather data and the sprays already selected. The forecast data were then used to simulate the rest of the year with different combinations of sprays. The programme that gave the highest profit with a spray on the decision day was found by an exhaustive search. This was then compared with each of the possible programmes with no spray on the decision day. If any of these had a higher profit the decision was not to spray, otherwise the crop was sprayed. The process was then repeated for the next decision day.

RESULTS

Table 2 lists the results obtained from these rules in terms of the increase in profit compared with unsprayed crops. It shows that, while the rigid calendar day and growth stage rules perform well in high risk crops they are poor on resistant crops. The best rule overall is the growth stage insurance method which, surprisingly, returned a higher mean profit than the ADAS managed control system. Comparison with the optimum programme, however, shows that even the best of these rules of thumb only achieved 75% of the potential profit. The model-based system returned 92% of the optimum profit.

Table 2. Increases in crop gross margins due to spray programmes (Means of 10 years, £/ha)

Crop parameters			Decision Rule					
Susc	Near WB	Early sown	Rule 1	Rule 2	Rule 3	Rule 4	Model	Optimum
Y	Y	Y	81.10	80.00	67.40	69.35	89.25	92.65
Y	Y	N	42.60	47.30	45.15	45.65	50.65	57.35
Y	N	Y	29.70	27.60	35.35	25.80	31.10	33.70
Y	N	N	8.50	10.40	14.30	14.05	16.70	18.55
N	Y	Y	1.70	6.70	7.00	- 2.60	7.05	8.30
N	Y	N	- 5.40	- 3.00	- 0.10	- 1.30	5.25	6.65
N	N	Y	- 5.90	- 4.10	- 3.25	- 2.70	0.00	0.30
N	N	N	- 9.60	- 6.70	- 2.40	- 1.40	0.00	0.05
Grand mean			17.83	20.52	19.18	18.36	25.00	27.19

DISCUSSION

The results clearly show the value of using as much information as possible in making spraying decisions, although Rule 4 performed surprisingly badly. The model has not been tested as a practical method of making spraying decisions, although it has been validated against trials results. The inevitable differences between the model and a real crop would have two effects: the model might not represent the current state accurately, and it might not predict the future development correctly. It would be unwise to drive the model by weather data alone and ignore the crop, indeed it would contravene the principle of using all the available data. It would be better to use the observations of crop and disease progress to adjust the state of the model and to adapt it to improve its future predictions. This applies to any use of this type of simulation in crop protection, and is an active area of research.

DIRECTIONS FOR FURTHER RESEARCH

Several general problems concerning use of mathematical models in decision making systems have been raised in the previous sections. Research is also addressing some of these.

1. Adjusting models in response to current local measurements

It is clear that models will have to be able to adjust and adapt themselves to local conditions by using intermediate data collected from the farm. Faivre (1990) describes one approach to this through the construction of linear predictors of error from analysis of historical responses of the model. Another possible approach is to estimate model parameters by using non-linear optimisation to fit the model to the local data.

2. Allowing for uncertainty in the decision method

However good the model, many sources of uncertainty will still remain including the weather, fungal innoculants from external sources and pest population movements. A first step in including uncertainty within decision support systems is to quantify the variability, usually in relation to the interval over which predictions are being made. Further research is needed into how uncertainty propagates through models and how uncertainty can be reduced through the use of intermediate measurements, which relates to the previous topic. Further research is needed into how to present uncertainty to decision makers, and how it affects their decisions through attitudes to risk.

3. Using local weather forecasts

Most of the technology now exists for national meteorological services to provide short-term local weather forecasts electronically, although these are not yet commonly available. This information could be used to improve short-term predictions of disease development, and to aid decisions about the suitability of the weather for spraying. The value of short-term forecasts in disease management needs to be assessed. If it proves to be valuable, the method of transmission and the information provided should be standardised.

4. Combinations of weeds or diseases

The models described have so far been developed only for single weeds and single diseases. In practice a farmer normally has to control more than one, and most chemicals are active against a range of weeds or diseases. The models may need to take account of inter-specific effects such as competition, and the effects of combinations of pests on the crop. The control strategies will also be affected: one treatment may control two problems, as with fungicides, or it might have opposite effects on different problems, for example, ploughing wild oats and black grass. It is more important to model complexes of diseases and mixed populations of weeds than to increase the detail of single-species models.

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DEVELOPMENT AND INTRODUCTION OF CROP MANAGEMENT SYSTEMS

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ABSTRACT
Since 1987 a structured development of crop management systems has taken place in the Netherlands. Based on a reference information model for arable farms, several crop management systems are developed (BETA for sugar beets, CERA for winter wheat and barley), or still in development (potatoes, Brussels sprouts and cauliflower). These systems focus a.o. on a field-specific advice on variety choice, fertilization, crop protection, weed control.

SIVAK has initiated and coordinated many of these projects . PAGV brings in agricultural knowledge and has an important contribution in information analysis and logical design.

Experiences with test groups of farmers show that these crop management systems will only be successful when being a part of an integrated farm management information system.

Both BETA and CERA will be available for the market coming winter.

KEY WORDS: Crop management, information model, integrated farm management information system, field specific advice

INTRODUCTION

The use of information technology is an important research theme in the field of practical research for arable farming and field production of vegetables in the Netherlands. On one hand the possibilities offered by informatics add a whole new dimension to the transfer of knowledge to the extension service and to farmers. On the other hand, the availability and use of information play an increasingly important role from the farmer's point of view in guaranteeing the continuity of his farm, bearing in mind the structurally worsening income-expenditure ratio and the constant tightening of regulations regarding the products and the method of production. The development of crop management systems and farm management support systems can make a significant contribution in this respect.

HISTORICAL CONTEXT

Crop management systems are modelled on Epipre[1]. In the late seventies Epipre has been developed by the Agricultural University in Wageningen and the Netherlands Grain Center (Drenth et al, 1989). Later on, other institutes like the Institute for Plant Protection (IPO) and also the Research Station for Arable farming and Field Production of Vegetables (PAGV) joined in. During several years the Epipre model has been tested and on a lot of arable farms. Improvements and further developments were made successively and turned out to be successful.

Thanks to Epipre, a lot of agricultural researchers discovered the potential possibilities and benefits in using computermodels for decision support of farmers at the operational level. Models to support the tactical and strategic decisions already existed before (Cuperus & Meijer, 1985). Several experiments were carried out in the field of developing computer programs for operational decision support. For instance programs have been developed for:

- determination of optimal timing to kill foliage of seed potatoes;
- field-specific registration of costs and benefits of crops;
- selection of herbicides for different crops;
- liquidity control.

[1] Epipre is an integrated pest and disease management system for wheat based on on-line calculations of costs and benefits of pest treatments.

In principle the developed programs did meet farmer's needs. Yet there were some important difficulties in using these programs by farmers or their advisors. As these programs were developed independently from one another, there was no interface between them. There was no common data base and in fact there was no common philosophy of the management process. It became very clear that there was an urgent need for standardization of definitions, classifications, algorithms and decision rules.

This lack of standardization was the main problem in all branches of agriculture in the Netherlands in the field of agricultural informatics.

STIMULATION OF INFORMATION TECHNOLOGY IN AGRICULTURE

A good information system is characterized by interrelated subsystems. On the basis of this, programs can be developed in which the subprograms are coordinated with each other and the data interchangeable. Furthermore, new functional specifications must be easy to integrate into the system. A good information system should provide an up-to-date picture of the part of the current situation relevant to the business or organization. It is therefore very important to have a structured approach and method (Scheepens, 1991).

With this and the experiences mentioned in the previous section in mind, the Government introduced the Stimulation Program for Information Technology in Agriculture (INSP). With this program the Ministry of Agriculture wanted to stimulate the developments and the use of information technology in the agricultural sectors.

In accordance with this policy branch organizations were founded to initiate and to coordinate developments on agricultural informatics on behalf of the farmers. SIVAK serves the interests of arable farmers, while SITU serves those of the horticultural growers concerning the supply of information.

Another important activity made possible by this Stimulation Program has been the development of information models for arable farms by structured information analysis of the farmer's decision making process. The following objectives are aimed for:

- uniformization of concepts, algorithms and decision rules;
- coordination and integration of present applications and systems;

- development of new applications;
- gaining insight into the need for research (Scheepens, 1991).

In the information model the activities and decisions which take place on an arable farm are described and illustrated by means of charts in the process model. All data used in these activities are incorporated in the data model. The link between the process model and the data model are illustrated in data flow diagrams.

Based on the Information Engineering Methodology by James Martin Associates, information models as outlined above have been developed for all branches of agriculture. The information models are intended as reference models for agricultural holdings belonging to the corresponding branches. In this way the information model for arable farming is considered to be representative to farms in production of arable crops, field vegetables and flower bulbs.

In 1987 an overall information model was finished. Starting from here, specific clusters have been worked out in detail to support the logical and technical design of agricultural information systems.

A MANAGEMENT INFORMATION STRATEGY FOR ARABLE FARMS

The branch organization SIVAK together with PAGV and other institutes have worked out a strategy for farm management support at various levels. In fact it is a strategy for the development of so called integrated farm management information systems; some elements of this structure are already operational, some of them are still under construction.

SIVAK has initiated and coordinated many of these projects, trying to involve as many organizations as necessary, including test groups of farmers and advisors.

PAGV brings in agricultural knowledge through crop experts, while farm management researchers from PAGV have an important contribution in information analysis and logical design.

The following scheme gives a rough overview of the state of the art of DSS for arable farming in the Netherlands in 1991.

DSS at farm level

- Farm Management Advisory (BEA)	operational
- Investment Planning	under construction
- Soil Pathogen Management (TERRA)	under construction
- Information of pesticides	projectplan ready
- Fertilization Advisory	feasibility study

DSS at crop level

- Sugar Beets (BETA)	operational
- Wheat and Barley (CERA)[2]	test in 1991
- Potatoes	projectplan ready
- Cauliflower and Brussels Sprouts	under construction

The farm management advisory system BEA is frequently used by advisors since 1988. The system consists of spreadsheet templates for production planning, labor planning and financial planning. It is used by the farm advisor to assist and support individual farmers in the long term decision making (Janssens & Krikke, 1990).

A DSS for investment planning is also constructed within a spreadsheet. The objective is to assist farmers in replacement of machinery from a farm economic point of view but also when tax policies are incorporated.

The DSS for soil pathogen management TERRA is focussed on the control of the potato cyst nematode by means of variety choice, soil sterilization (only permitted restrictively in the near future!) and crop frequency. This project has only started recently and it will take at least a few years before the first prototype can be tested on arable farms.

The objective of the information system for pesticides is to create a knowledge base for all types of chemicals for weed- and pest control, containing all relevant data related to crops and environment effectiveness. This knowledge base is considered to be necessary for the effective maintenance of crop management systems.

[2] including Epipre

THE CROP MANAGEMENT SYSTEMS BETA AND CERA

When growing crops, farmers take various cropping decisions. Some examples of such decisions are the choice for one or more varieties, the decision whether or not to carry out a chemical treatment against weeds or pests, the determination of the optimal harvest period of a crop, etc.

Besides cropping decision are taken on several moments during the growing season. For instance the variety choice will be made only before the start of the growing season, while the decisions on weed- or pest control are taken frequently during the whole growing season. Crop management systems are installed on the farmer's own personal computer. A crop management system offers the farmer farm- or field-specific information to support him in taking cropping decisions. The ultimate decision however remains the responsibility of the farmer himself.

In crop management systems the global management cycle - plan-ning, implementation, control and evaluation - can be recognized in the following key functions:

- Crop planning
  This involves the draft of an executional plan specific to a certain crop, based on the farm's production plan which has already been determined.
- Cropping support
  The objective here is to support the farmer in taking the different decisions concerning the growing of the crops. The extension service only give general information and general advice to farmers by publications in journals, by presentations, etc. In crop management systems however, the available knowledge and information from agricultural research is combined with farm- and field-specific data to generate farm specific information and advice. In this way support is offered especially on variety choice, crop protection, pest management and fertilization.
- Control and evaluation
  The cropping treatments which have been carried out are registrated. Afterwards their results are compared with the original plans. Differences between planning and corresponding performances are to be analyzed to adjust future plans.

Based on this strategy the crop management systems for sugar beets (BETA) and cereals (CERA) have been developed using 4GL-tools. The BETA and CERA projects were divided into seven phases. This splitting up of large projects in several stages offers better starting points for project management.

After each phase it is decided whether to continue the project or not. The following phases can be distinguished:

- information analysis: what are the most important decisions taken by farmers concerning crop production; what about the complexity of the problems in question, the availability of data and knowledge;
- information modelling: structuring knowledge and data in a proces model and a data model; feed back with the information model for arable farming;
- create a logical design of the crop management system;
- drawing up a technical design;
- programming of the system;
- introduction to the test groups of farmers and advisors;
- evaluation (De Jong, 1990).

In 1991 both DSS have been tested intensively by farmers and cropping advisors from the extension service and the sugar companies. Also some software organizations have carried out a thorough market orientation among arable farmers. Their market study which has been carried out this summer has been translated in a strategy for control and maintenance of these DSS on a self supporting base.

From the development and introduction of BETA and CERA the following experiences can be noticed:

- Crop management systems like BETA and CERA are so called knowledge intensive systems. The development of these systems are risky projects and can only be carried out successfully when being financed by public organizations (research station) and/or profit masterorganizations under the condition that the initial development costs will be written off at once. Only then distribution, maintenance and control of crop management systems can be carried out on a commercial basis.
- The training of advisors and farmers and also the on-farm support by advisors is very important for a successful introduction.
- Formalization of agricultural knowledge is much more difficult than expected at the start of the projects. A lot of research in the field of Knowledge Engineering has to be carried out to really generate (and improve) farm specific advice.
- The farmers who were involved from the beginning of these projects are positive in their judgement, especially with respect to the subjects variety choice, consideration to carry out chemical treatments against weeds and

pests, choice of pesticides and fertilization. Also a new group of farmers who have tested BETA for the first time in 1991 reacted positively.

NEW DEVELOPMENTS IN CROP MANAGEMENT SYSTEMS

In 1992 the programming and field tests of the crop management system for cauliflower and Brussels sprouts (KOBAS) will be carried out. The scope of this project will be restricted to a few modules only, in accordance with the experiences so far in arable farming. On the other hand these modules are considered more or less representative for a lot of other vegetable crops.

Also in 1992 crop management activities for potatoes will start. Extra attention will be given to the promotion of datacommunication facilities (EDI, file transfer). Especially for potatoes a lot of data are transferred between farmers and trading organizations.

Besides these projects new research activities will focus on the improvement of crop decision models and damage relations for pests. New research projects are in preparation with respect to variety choice, weed- and pest control and fertilization. An important goal of practical research for arable farming and field production of vegetables is a reduction in dependance on chemicals and their use. In the farming systems research, all crop measurements are integrated in farming systems, with the aim of achieving optimum farm management with a maximum economic return and a minimum use and emission of chemical pesticides and fertilizers. In this respect farming systems research also makes a significant contribution to the development and improvement of crop management and farm management systems.

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DEVELOPMENT OF AN INTEGRATED CROP PRODUCTION PROGRAMME FOR WINTER WHEAT

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ABSTRACT
Optimal use of crop production factors in winter wheat cropping requires optimal use of the interactions among the various factors. The majority of the research has until now concentrated on optimizing single or simple combinations of input factors. Advisory systems have similarly been designed to cover only one or a few disciplines.

There is a need for further research on the interactions between crop production factors. This knowledge may be used by farmers through an integrated crop production programme for winter wheat. This requires that the knowledge is represented in a model covering several research disciplines. It must also be possible to optimize the use of input factors in such a model system.

A Danish winter wheat project has been started, which aims at providing an integrated crop production programme for this crop. The project will provide a framework for a close collaboration between modellers and researchers from several research disciplines.

KEY WORDS: Modelling, interdisciplinary research, field experiments.

INTRODUCTION
Changes in both the rural and urban societies put increasing emphasis on both farm economy and environmental impact of crop production. This causes increasing demand for planning and control in crop production.

Within the EC there are expectations for lower intervention prices. Lower prices implies lower costs for cultivation, if profits are to remain at the same level. Lower prices will ultimately cause certain cultivation practices to be abandoned.

The Danish government has issued plans for controlling environmental impact from agriculture. Nitrate leaching from soils should according to the plans be reduced by 50% over a five year period. At the same time use of pesticides must be reduced by 50% by 1997 with the period 1981-85 as the baseline.

The necessity to integrate economic and environmental factors has lead to the concept of sustainable agriculture. Geng et al (1990) defines sustainable agriculture as a system, which is profitable for the farmer, which gives adequate amounts of healthy, high quality foods, which minimizes use of ressources, and which does not have adverse environmental impacts. Geng et al (1991) found that sustainable agricultural systems could most effectively be developed using system analysis as a framework for defining interactions in the system. Models can then be developed from existing knowledge and data. Simulations with the models can identify areas with missing knowledge and data. This can then provide a basis for specific experiments and investigations.

The area with winter wheat has increased in Denmark over the past few years. Winter wheat is potentially a very productive crop, but in traditional cropping it requires considerable inputs of fertilizers and pesticides. There is a large knowledge base on the effects of single crop production factors. The knowledge on interactions between crop production factors are more limited. Such interactions are important when reducing inputs and keeping profits high.

Winter wheat has been chosen as the model crop for developing an integrated crop production programme in Denmark. The objectives of this project is to develop an advisory system for winter wheat production. This advisory system should optimize inputs in relation to farm profit and environmental impact by taking the most important effects and interactions into account.

A prepatory project has reviewed the existing knowledge on winter wheat cropping in Denmark and Northern Europe (Olesen et al, 1991). In addition to the review a system analysis of the winter wheat crop production system has been made. The review and the system analysis points at important interactions, which can be utilized for reducing inputs. This, however, requires further research, as the reasons for the interactions are often poorly understood. A research project has been started to clarify the most important interactions and to describe these effects in an interdisciplinary model. This model will be used to develop an integrated computer based advisory system for winter wheat.

WINTER WHEAT PRODUCTION SYSTEM

A number of factors and farming practices is included in the winter wheat crop production system. This is illustrated in Fig. 1. Plant growth is the essential element of all crop production systems. All other factors interact with the plant growth. The result of the plant growth is a marketable yield of a given quality, which contributes to the overall economy by providing an income. Most of the management factors contribute to the economy by providing a cost. The left hand side of the figure shows some factors, which are not influenced by management, but which none the less significantly influences plant growth.

Some of the management factors in Fig. 1 also has environmental impacts, either directly or indirectly through interactions with the plant growth. In addition irrigation has consequences for the water ressources. The plant growth in Fig. 1 should be viewed in a broad sense, including also effects such as nitrogen turnover in soils and disease and pest progress.

Table 1 shows the distribution of costs in Danish winter wheat production to parts (fertilizer, pesticides, grain drying etc.), machines and labour. The costs allocated to labour is relatively small, and does not include general management costs, but only the direct labour costs for carrying out the field operations. The major costs, which can be changed are costs for purchasing fertilizer and pesticides, and machinery costs for soil cultivation and sowing.

Table 1. Distribution of costs (pct.) for growing winter wheat on a loamy soil in Denmark. Calculated from Landbrugets Rådgivningscenter (1991) assuming a labour rate of 145 DKK pr. hour.

	Parts	Machines	Labour	Total
Fertilization	14	2	1	17
Pesticides	11	6	1	18
Soil cultivation and sowing	7	11	6	24
Harvest	7	29	5	41
Total	39	49	12	100

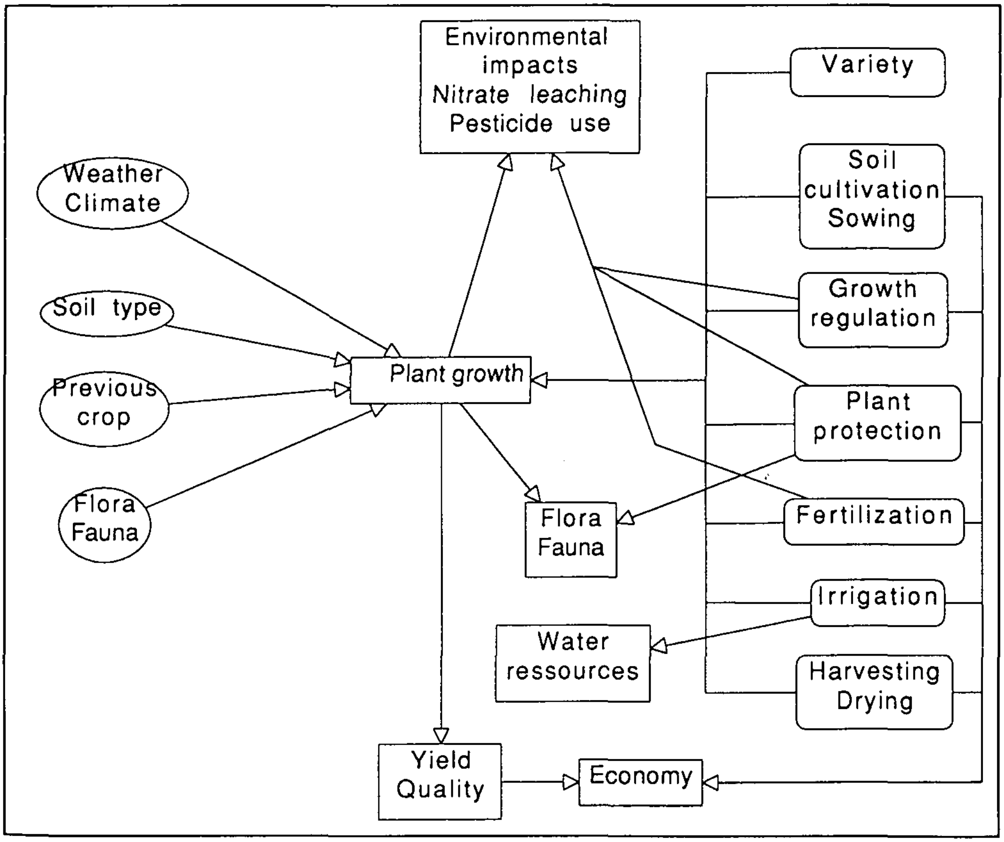

Figure 1. Factors involved in the winter wheat crop production system.

EXISTING KNOWLEDGE AND DATA

A lot of experiments has been carried out examining the effect of single crop production factors in winter wheat. Such experiments do not give information on interactions between crop production factors.
Factorial or multifactorial field experiments may produce such information. This, however, requires carefull planning of measurements in the experiments. Measurements must be made at several points in time to explain the reasons behind the interactions. Such measurements must be done in an interdisciplinary manner as demonstrated in a multifactorial experiment at Rothamsted by Prew et al (1986).

Multifactorial and factorial experiments have show that important interactions exist between a number of input factors, e.g.:

- Nitrogen fertilization and some fungal diseases.
- Plant density and some fungal diseases.
- Nitrogen fertilization and lodging.
- Plant density and lodging.
- Soil cultivation and weed competition.
- Sowing time and weed competition.

Most of these interactions depend heavily on which varieties are used, and on the actual weather conditions. Soil type and previous crop may also play a role in determining the interactions. It is thus not possible to infer general rules about these interactions from traditional field experiments. Further knowledge about the dynamics of the interactions are neccesary before advisory systems which accounts for such effects can be deviced.

MODELLING PRINCIPLES

Modelling is increasingly being used for studying interdisciplinary problems (Penning de Vries, 1990). The objectives of modelling are many, e.g.:

- To obtain a larger understanding of the functioning of the system through description of the interrelation between the elements of the system.
- To extrapolate knowledge to cover circumstances or factorial combinations not directly covered by experiments.
- To use models for planning and control in crop production.

Crop growth models have mainly been used to obtain a larger understanding of the soil-plant-atmosphere continuum. In some cases models have been used for planning purposes, e.g. selection of cultivars in semi-arid regions. Existing crop growth models are rarely used for scheduling farm operations i practice. This is partly because these models often does not contain effects of all important factors, e.g. pests and diseases, and partly because many models are not directly suitable for optimization purposes.

The simplest type of modelling is use of regression techniques. This method does not give a valid description of complicated interactions, and can thus not be used for extrapolating knowledge.

As plant growth is the result of many interacting processes over a period of time, it is natural to describe the system by changes in the system variables as rates and differential equations. This is called dynamic and deterministic modelling. This method has also been used to describe processes in the soil and in the atmosphere. Dynamic and deterministic modelling is the most popular method for simulating crop growth. The use of differential equations integrated over time, however, makes this method unsuitable for optimizing decisions in other than trivial situations.

An other technique for describing systems is the use of causal probabilistic networks. This method is related to expert system technology and has until now mainly been used for developing medical diagnosis systems (Andreassen et al, 1990). The network is described by a non-cyclic graph, and the relations betweeen variables are described by conditional probabilities. Such a network can directly be used for optimization purposes, and it is also possible to insert observation at any point in the network to provide better estimates.

EXISTING ADVISORY SYSTEMS

In the 1970ies EPIPRE was developed in the Netherlands as an advisory system for control of pests and diseases in wheat (Zadoks, 1989). Similar systems were adapted in a number of other European countries. In the recent decade a number of other computer advisory systems has emerged. Some of these rely on databases combined with some modelling, while others use expert system technology.

In Denmark there has been an attempt by the advisory service to develop a total computer advisory system for planning and control of the entire farm. This system is called Bedriftsløsningen. The system will contain modules for fertilization planning, weed, pest and disease control, and irrigation scheduling.

Characteristic for the existing computer-based advisory systems is that they only encompass a single or two agricultural disciplines, but a lot of crops within those disciplines. This makes is impossible to represent interactions between important factors such as nitrogen fertilization and disease progress in those advisory systems.

NEW ACTIVITIES

A five year winter wheat project has been started in Denmark. The activities in this project will concentrate on developing an integrated model for winter wheat production. Fig. 2 outlines the structure of this model. The total model contains a number of submodels, which interact as shown in Fig. 2.

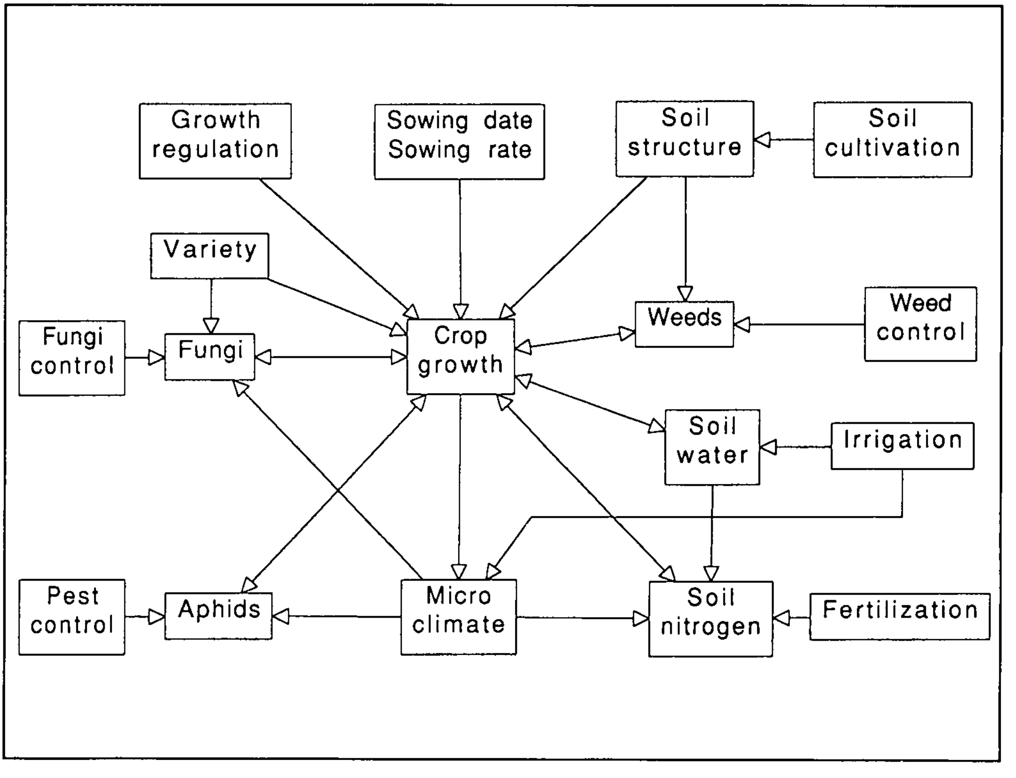

Figure 2. Submodels in the integrated winter wheat system model.

Crop growth is the essential part, through which most submodels interact. If these interactions are to be properly represented, then the model needs to by dynamic in time. The crop model will include variables such as:

- Dry matter in roots, stems, leaves and kernels.
- Leaf area index in different horizontal layers.
- Plant density.
- Crop height.
- Lodging.
- Number of spikes and kernels pr. unit area.
- Extinction coefficient for light and various fluxes.
- Nitrogen content in the crop.

Processes covered by the crop model will include:

- Photosynthesis and respiration.
- Growth rates of dry matter, leaf area index etc.
- Death rates of leaves, roots etc.
- Nitrogen uptake.
- Effects of various factors on canopy structure (extinction coefficients).

The other models will interact with these variables and processes. Some of the submodels require small time steps of about a day to represent the dynamics, e.g. soil water balance, while other submodels are restricted to only a few time steps, e.g. soil cultivation. There is also a large variation in the type of knowledge available for developing the various submodels.

It is intended to develop the models as causal probabilistic networks. This method makes it possible to:

- Represent the current understanding of interactions in the crop production system.
- Use experimental data to parameterize these interactions.
- To represent uncertainty in the current knowledge on interactions and uncertainty in measurements used as input to the models.
- Calculate an optimal strategy for use of input factors such as fertilizer and pesticides from knowledge on previous treatments, climatic conditions etc.

It is probably only possible to represent this large system of interactions by concentrating on the major ones. The model will be further developed to a PC-based advisory system for use by agricultural advisors and farmers for optimizing cropping strategy in winter wheat. Decisions in this system must be optimized in relation to economy and environmental impact. Farm profit is the most important of these factors for the implementation of such a system in practice.

Besides providing a final winter wheat crop production programme, the winter wheat project will also within the five year project period release submodels and paper-based advisory systems for use by farmers and advisors.

The model development will be supported by a number of field experiments. This puts a number of demands to the experiments:

- There must be agreement between the measurements in the experiments and the variables in the model.
- The experiments must deliver new knowledge to the models, where such knowledge is essential.
- The experiments must provide data for quantifying interactions represented in the model, and for validating the model.

The experiments in the project will be a combination of multifactorial experiments for providing validation data and factorial experiments for providing data for quantification of interactions. Most of the experiments must be interdisciplinary in order to provide the range of measurements required for use in quantifying interactions.

One of the important questions to be answered by the project is how to represent differences in responses by different varieties. This may be done by defining new variety characteristics (e.g. in canopy structure) and using these characteristics in the model.

CONCLUSION

Sustainable farming systems require better use of the interactions between crop production factors in order to ensure reasonable farm profits at lower environmental costs. This is only possible by a better understanding of the interactions, and this understanding must be operational, i.e. usable to farmers and agricultural advisors. Use of models and computer programmes is a way to make this knowledge operational.

Previous experimental methods comparing different experimental treatments over a number of years at several locations often only gives information on general differences between treatments. The statistical methods used are designed to test such general differences. In other words, the null hypothesis is that there are no difference between treatments.

Interactions between treatments are often very variable from year to year and location to location. This may be due to differences in soil type, climatic conditions etc. A traditional experiment will not provide operational information on these interactions. This requires understanding of the fundamentals of the interactions. Thus the null hypothesis needs to be the current understanding of reasons for the interactions. It will probably only be possible to handle this, if this knowledge is represented in a mathematical model, which can be confirmed or rejected.

Such a model can then be used as a basis for constructing a computer-based advisory system. Identifying and quantifying the major interactions in the winter wheat cropping system is a large tasks, which require several years and collaboration among several research disciplines. This will probably also be usefull in other aspects by identifying new areas of research.

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CD-ROM - AN OUTSTANDING TECHNIQUE FOR DESTRIBUTING INFORMATION

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ABSTRACT
In Sweden, like the rest of the world, information concerning plant protection is coming from several different sources. The result is often a very good coverage of diverse topics, but published in separate publications and therefore hard to reach for the users. CD-ROM is an information technique which combines high efficiency with low costs. In Sweden we have initiated a project to collect plant protection information from many different sources on one CD-ROM disc.

KEY WORDS: CD-ROM, plant protection, information.

INTRODUCTION
Modern agriculture is a integrated part of the information society. Plant protection is a good example, where a large amount of information concerning weeds, pests and diseases are processed. This information include facts about weeds and pests, treatments, chemicals, laws and regulations, recommendations, etc. The flow of information is considerable and changing very fast, even in this limited sector of agriculture. This information is also coming from many different sources, for example extension, universities, state departments, private companies etc. This makes it difficult and time consuming for the user to find the information which is relevant and up to date.

A group of six persons have investigated the future need for computer aided support within the plant protection sector in Sweden. This article is a summary of the final report, named 'Computer support within the area of plant protection' (in Swedish).

TARGETS GROUPS

There are several different target groups for information within the plant protection sector. Each group have both general and specific demands on the information, but all users needs more efficient ways to find it.

The farmer needs information about; identification, thresholds, choice of treatments, techniques, chemicals, doses, timing, costs, personal protection equipment and how to protect the environment etc. The extension worker and selesmen need more background information about pests, chemicals,methods, results from field trials, laws and regulations etc. The governmental administration, private companies and universities also need facts about plant protection, for instance; statistics, active ingredients, how to handle debris, specific publications, investigations etc.

There are no clear borders between the groups, and much of the information is essential for several users within different groups.

TODAYS INFORMATION

In Sweden, like the rest of the world, the information is coming from several different sources. The most important, within the plant protection section, are the Swedish agricultural university, state authorities, private firms, magazines and different growers organisations. All these are producing information resulting in a very good coverage of diverse topics, but published in separate publications and therefore hard to reach for users with limited time.

THE NEED OF A DATABASE

The growing demands for relevant and updated facts, in combination with todays confusing distribution system of information, accentuate the urgent need for a more modern handling of information. A database, which contains collected and easy to use information, is therefore required.

Several attempts have previously been made to create databases, mainly online, with this type of information. The results are discouraging. Very few have used these databases, mostly because of user difficulty, too narrow selection of information and expensive online searches.

The demands on a database, with different target groups, should therefore be:
- Possibilities to store all types of relevant **existing** information within specific topics.
- Easy to use without previous knowledge of computers.
- Handling both text, picture and sound.
- Easy to update and distribute.
- Reasonable price.

CD-ROM

Of the existing information techniques CD-ROM is best in satisfying the demands above. (In some cases when the information has to be updated continuously, online databases are the only alternative.) The motivation for this is both technical and human, and can be summarised in the following statements:
- A Compact Disc (CD) can handle approximately 250 000 pages of text (Å1 ton paper). This makes it possible to collect information within an area on one disc. There are also enough place to collect information from previous years.
- On the same disc both text, colour pictures and sound can be stored.
- All information collected on one disc can easily be searched in seconds.
- The use of information in computers will never be fully accepted until the screen and print layout can be comparable to paper based information. This includes layout and use of pictures etc. This is already possible in several layout programs such as PageMaker, and will also be possible with CD-ROM within some years.
- With a graphic interface, search programs can be made very user friendly. There is also a fast increasing use of computers among ordinary users. This makes it much more possible for a breakthrough for electronic databases now, compared to some years ago.
- A user who adopts the CD technique, will also benefit from numerous CD-ROM titles covering all types of information.
- A CD player can be used together with an ordinary computer (with colour screen).
- The CD technique has an international standard and function on different computers such as IBM and Macintosh.
- Production costs are very low, approximately some dollars per disc. Instead the main costs are the licence for the retrieval program and the information on the disc.
- Not susceptible to data virus.

To continuously handle and update information from many sources it is of great importance to organise the work efficiently to keep the costs low. In the start of a CD-ROM project the work is concentrated on transfering old paper based information into electronic form. Later, when most of the material is produced in electronic form at the source, the producers have to be convinced to tag their own material in an uniform way. SGML (Structural General Markup Language) is one example of an international standard for a more easy handling of electronic information in different media.

Copyright regulation on information in electronic form are similar to these of text and pictures. This can restrict the use of interesting information on a compact disc if no agreement can be made with the producers.

CONCLUSIONS

Profit within the agricultural sector are decreasing and the state input of money for research and development too. This makes it more difficult to develop and maintain complicated information systems. To develop properly, a fast changing agriculture must have more efficient ways to reach existing information than today. CD-ROM is an information technique which combines high efficiency with low costs.

There are many reasons why Compact Discs will be commonly used within agriculture. The main reasons are the more user friendly programs and the fast growing use of computers. To this can be added the possibility to collect huge amounts of information on one disc with outstanding search possibilities. This information can also be presented in a form in which we are used to from paper based media.

The information on a CD-ROM can be found and used right at the desk. The cost for the extra equipment, apart from a computer, are also small. The potential target groups are therefore all those who are interested in the information on the disc, have a computer and are prepared to purchase a CD player for approximately 600$.

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VOICE RESPONSE DATABASES IN PLANT PROTECTION WARNING SYSTEMS

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ABSTRACT

A dbase III+ application has been developed around a voice board system at NPPI. The voice system is PC-based and one board allows four users to interact with our plant protection databases simultanously. Both regional plant protection warnings and climatic data are daily updated. The routines produce voice messages in the form of DOS files. Small fragments of sentences are combined by the dbase application to produce spoken messages. A most promising field for this application is the use of an ordinary telephone apparatus to enter plant protection data directly into our databases. The interaction between the farmer and the databases allows the warning system to respond individual data with individual advice.

INTRODUCTION

The proliferation of 'tele-market' services over the last two years has paved the way for plant protection advisory service.
Some of these services are very time critical and the 'tele-market' concept is very well suited to give plant growers on-line advice.

By linking the telephone service to our existing PC databases already serving the extension offices, a very fast, efficient information system has been developed. Only imagination will limit the way the voice response system can be used. So far, we have developed these different types of service;

1. Disease/pest summaries daily updated from the farmers monitoring in their own fields.
2. Climatic data from some 30 on-line loggers.
3. Disease/pest recommendation to individual farmers based on their field observations.

MATERIALS AND METHODS

The voice response system is centered around a voice board in a PC. The board 'NITA', may serve four telephone lines simultaneously. The system can be extended with a second board to improve performance. Basic operation of the board is handled by a factory delivered driver, whereas a third party company has developed a dbase III+ application that allows us to easily modify the services.

The voice data is stored as DOS-files and is recorded through an ordinary telephone connected to the voice board.

The system works only with tone signals. Some users therefore have to set their telephone apparatus in tone mode in order to communicate with the board.

PERFORMANCE OF THE VOICE BOARD

Apparently the voice board itself is capable of handling the voice reproduction very well.

Large amounts of standard phrases, numbers, name of months, name of counties etc. exist in prerecorded files. The plant protection expert databases and climatic databases are updated every day from the main application. Self-developed dbase III+ programs update the respective audio-files every day by combining small fragments of sentences. This links the standard PC databases to the audio system. About 50 MB of data is generated every day to produce the working files.
All kinds of 'static' information i.e. information that does not change due to the callers actions, lends itself very well to batch prosessing. This way of synthesizing voice-files also improves the overall performance of the system.

Another feature of the voice-board system is the possibility for the caller to have an individual dialog with the plant protection expert databases. The system will give an individual spoken advice generated on the basis of the farmers input and the plant protection models.

So far we have not tested this application on end users, but similar applications have been running in Norway for some time.

AUDIOTEX: TECHNOLOGY FOR DISSIPATION OF INFORMATION TO A LARGE POPULATION

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ABSTRACT
Telephones are the most familiar and easy to use communication device. Since it is widely available and can be linked to computers without using a modem or display terminal, it can provide wide accessibility of the computer systems. Audiotex are telephone-based voice response systems where the information in the form of voice is supplied in an interactive environment through online access to a computer using voice or tone recognition.

An audiotex for monitoring and control of pests in sugar beet was evaluated by 22 Danish farmers. The result show that the system is simple to use and has the advantage in giving recommendations immediately after providing the field information using the phone keypad. Because of the simplicity in use and wide spread availability of telephones, audiotex provides a simple means for extending the plant protection information to a large group of farmers.

KEY WORDS: audiotex, voice response system, telephone.

INTRODUCTION
Voice is the first method people learn, and has been shown to be the fastest and most productive means of interactive problem solving. For most people, it is also the most commonly available communication modality and is easier than reading and writing.

Use of voice as a communication modality between humans and computer is not new. Technology has been available for more than a decade, but they have not been integrated into information systems to a full extent due to several reasons. The state-of-the-art technology in automatic recognition or generation of speech are still not adequate and/or affordable for many applications and design of a good user interface has proven difficult. Furthermore, conversation requires a thorough understanding of the language structure and formulation, and people are relactant to converse with the machines. Although a normal human conversation with a computer is still not fully achieved, voice communication is gaining a foot hold.

Voice technology can be broadly grouped into the following 3 major categories (Aucella et al, 1987):

Speech compression. Systems allows analog patterns of human speech to be digitilized and stored in the digital form. These stored information can be transmitted and played back as systems output. Common applications are voice mail, voice annotation.

Text-to-speech. Systems allow computer-stored text information to be translated and played via a voice synthesiser. Common application are remote retrieval of electronic mail, bank account statement.

Speech recognition. Systems allows analog patterns of human speech to be translated into their text-based equivalent or into computer commands. This provides the most direct communication between humans and computer. Common applications are data entry, voice activated typewriter.

Although major improvements have been made in each of these categories, the most commercial applications have been made in speech compression because of the availability of good quality compression hardware and software at a very low price ($150 to $16,000). Speech recognition is still limited due to its susceptibility to noice and variation in the users voice due to illness.

These systems are collectively called as Audiotex and refers to services where the information in the form of voice is supplied in an interactive environment through online access to a computer using voice or tone recognition, usually through the use of a touch-tone telephone. The users control of system is through the telephone or voice. The present applications of audiotex include banking and financial services, company information, travel and reservation systems, health services, mail order entry, subscriber information and telephone directory.

A recent survey, done for the European Commission, estimates that in 1989 the total of revenues for service providers, information providers and manufactures of audiotex was about 300 million Ecu. Of this the UK has revenues of 250m Ecu, France 30m Ecu, Denmark 7m Ecu, Germany 1.5m Ecu and Belgium and the Netherlands 9m Ecu. By 1993 the European market revenue could be of the order of 700m to 1200m Ecu (Anonym, 1991). The various reasons for the economic success of audiotex are that communication can be established with a touch-tone telephone and it does not require video display terminal and/or modem on the part of the user. The simplicity of the phone keypad provides easy user control of the system. Furthermore, telephones are easy to use, familiar interface, widely accessible, available 24-hours and it can be used by blind people.

In this article, I shall be presenting an audiotex system, based on the speech compression technique, developed at the Centre for monitoring and control of pests in sugar beet. The objectives of the project are to provide timely recommendations on plant protection and to evaluate audiotex as a means of communication.

AUDIOTEX FOR PLANT PROTECTION SERVICE

Monitoring and control of pests and diseases in various crops has been undertaken by the Center since 1987 using a relational database system (Murali, 1990). The major disadvantage of the system has been that the recommendations reach the farmers 24-36 hours after the recording of the pests and diseases in the field since the communication is by post. Delays can be even longer during weekends and holidays. In order to provide timely plant protection measures and to extend the accessibility of the advisory service, the relational database system was integrated with an audiotex system.

The audiotex system functions as follows: When the user called the audiotex using a touch-tone telephone, the system played a welcome message and described how to correct the input in case of any mistakes. Thereafter, the user was required to enter his/her identification number and field number using the telephone keypad. The system checked for the existence of these numbers in the database and in case they were valid, it continued with the entries for the field observations. The sequence of data entries were as on the field registration card which was used during the field observations. The number of entries varied from 6 to 12, depending on the farm activities performed since the last field registration. Messages before each data entry were short and specific to the data and contained information on how to terminate each entry. The numbers entered by the user were repeated by the system and it was possible for the user to listen to a message again or reenter field data with the help of # key on the telephone keypad. After the last data entry, the system stored the data on the database and immediately evaluated the data and recommended the control measures. All activities on the telephone keypad were logged by the system for usability analysis. At the end of the day, for each of the system user, the system printed recommendations, regional pest statistics and the next registration card. These were sent by post.

EVALUATION BY THE END USERS

For evaluating the audiotex, 30 farmers were randomly selected from the relational database system. The selection included participants from all the regions of the country and also covered a wide range of farm areas.

The participants received a printed instruction on how to use the audiotex with a touch-tone telephone, a field registration card with farmer's ID and field ID and a questionnaire on the usability of the system. The instructions also included what measures to take if any mistakes were made while using the audiotex and the users were requested to record the mistakes in the questionnaire. The field registration card with the ID numbers were identically similar to the one used in the relational database system. The audiotex was evaluated from the mid of July to the beginning of August, which corresponds to the end of the normal monitoring period.

RESULTS

Of the 30 selected farmers, 22 evaluated the system and only 1 farmer did not have a touch-tone telephone. Since the system was implemented towards the end of the monitoring period, it could not be used more than 3 times for each field. The number of times the system was used by each user varied from 1 to 3 and the average was 1.8, with a total of 39 calls. The length of each call varied from 2 to 5 minutes and the average call length was 2.6 minutes. There was only one data entry error and this was immediately corrected by the user. The mistake was that the user interchanged the ID numbers.

The evaluation on the usability of the audiotex show that the system is easy to use, telephone is a preferred interface to post, and the audiotex will be used all through the season in all crops (Table 1). The users have commented that the audiotex is well suited for plant protection recommendation services. The comments and suggestion that were made by the users were as follows:

"The new system is excellent and gives immediate response".
"It is simple and easy to use".
"Telephone should be open day and night".
"It is important that audiotex is fast and simple to use".
"It should be operated as one unit combining the other crops".

TABLE 1. Results from the evaluation of the audiotex system for monitoring and control of pests in sugar beet. Systems usability analysis. Average is from a scale of 1 to 10, with 1 representing the low end and 10 representing the high end of the criterion.

Criteria	Scale	Results			No. of responses
		Minimum	Maximum	Average	
Is the system user friendly ?	1 = not at all 10 = absolutely	7	10	9.1	18
Is the use of telephone a good idea ?	1 = very poor 10 = very good	1	10	8.8	19
Will you use the system all through the season ?	1 = not at all 10 = absolutely	5	10	9.7	18
Will you use the system if it is extended to include other crops ?	1 = not at all 10 = absolutely	1	10	9.5	17

DISCUSSION

Timely availability of information is a vital factor in the decision making. In the relational database with postal communication, 1-2 days lapsed between the field recording and the availability of recommendations. On the otherhand, with the audiotex system, recommendations were available within 2-5 minutes after calling the system. The total time required depended upon whether a mobile or stationary telephone was used and in extreme cases it would have taken a couple of hours from the field recording, since telephones are widely available. With the implementation of the audiotex, the Research Centre is able to obtain the actual status of pests 1-2 days earlier than the postal-based relational database system. Furthermore, it has reduced the manpower requirement at the Center and the data entry errors, since the work is done by the farmer.

In Denmark, audiotex has been used in providing information such as general health, employment opportunities, newspaper subscription and travel service. But the present study show that audiotex can be effectively used as a decision support tool in commercial production. This is supported by the positive response from the end users in their willingness to adopt the system covering a wider range of crops. Because of the simplicity in use and wide spread availability of telephones, audiotex provides a simple means for extending the plant protection information to a large group of farmers.

FUTURE DEVELOPMENTS

The audiotex has proved successful in its goal to reduce the time required to obtain recommendation service. Farmers have also expressed their interest in using the system when it is extended to include other crops. It is planned to convert the entire postal-based relational database to audiotex system by spring 1992.

Correct diagnosis of pest and disease is a prerequisite in the optimal plant protection. Diagnostic tool such as expert systems have been shown to have a high degree of precision in the diagnosis. Since computer-based expert systems have the limitation of the physical portability, accessibility of the diagnostic tools can be extended if they are integrated with an audiotex system. An expert system shell integrating an audiotex system has been developed and the knowledge bases for the identification of aphids and pests are under preparation.

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