COMPUTER AIDS FOR PLANT PROTECTION, HISTORICAL PERSPECTIVE AND FUTURE DEVELOPMENTS.

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Initiatives like: Videotext and forecasting models, resulted in a relatively fast introduction of computer technology on farms at the end of the eighties of last century. Most models were developed for diseases that could expand very rapidly, or diseases that should be controlled regularly. Later on the data exchange was digitally. In the nineties of last century, the development of the weather-related Decision Support Systems (DSS) started.

Important is to use the most optimal way of dissemination of information to the target group; this can differ between countries or even within countries. The use of DSSs results in a lower risk of damaged crops by diseases and pests, and a lower input of active substances, by using adjusted dosages. Future perspectives show a possibility of implementing a number of the DSS-models in a Geographical Information System (GIS) environment, and support the precision agriculture by making adjusted spray advices based on plot specific circumstances.

Besides the success of the DSSs, it is a disappointment that the development of the majority of the Decision Support Systems took place separately in a number of countries. The speed of improvement could have been on a substantial higher level when there was a real and clear cooperation between countries or groups of researchers. Also the accessibility of DSS’s through modern ways of communication could be improved upon.

INTRODUCTION

Since the middle of the eighties of the last century there were a lot of developments in programs that could be used on farms as an aid to support farmers in taking decisions to manage their farms. Decisions as when to spray what kind of plant protection product is the most optimal and what is the optimal dose. EPIPRE (Daamen, 1991) was one of the first computerised advisory systems for supervised integrated control in Europe. Soon after the introduction of personal computers and modems on farms, there were in several countries governmental funded programs. These programs stimulate the introduction of this new information technology, the use of personal computers on farms and also the development of models or other possibilities to exchange information (Meijer & Kamp, 1991). Furthermore there were some EU funded concerted actions (EU.NET.DSS) and EU-cost actions to stimulate the development and introduction of this new information technology as a common initiative (Secher, 1993).

HISTORY

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VIDEOTEXT

At the end of the eighties there were developments of videotext advisory systems for farmers e.g. in Germany, Belgium, Ireland, the Netherlands and Switzerland (Carletti & Claustriaux, 1991, Dunne, 1991, Forrer et al., 1991). Through these systems information was transferred on: weather, crop varieties, plant protection products and advice on how to use this information. These initiatives resulted in a relative fast introduction of the computer technology on farms, but the advices of these systems were very general and not very customer tailored or field specific.

More customer tailored were developments at the Norwegian Bulletin Board (Magnus et al., 1991). Farmers could dial into a system and download the daily updated specific pest and disease warnings, together with the weather prognoses.

ADVISORY MODELS, THE FIRST STEP TO DECISION SUPPORT SYSTEMS

Since the mid-eighties there have been developments in a number of countries to create models for supervised control, e.g. in Norway, Denmark, Spain, United Kingdom, Germany, the Netherlands, Italy, France and Sweden. Most models were developed for diseases that could expand very rapidly, or for diseases that should be controlled regularly e.g. Potato Late Blight, Apple scab, Cereal leaf diseases and Grape downy mildew. Most of these advisory models used observations and countings of the disease severity and/or incidence carried out by the advisor or farmer, to compare with a set of threshold values for the respective development stage of the host plants. These data were used as economic threshold to calculate if an application could be advised. This was the first step in the support if the decision of a spray application was necessary, with the help of computers. The information exchange to the central host (mainframe) computer in the first years was by normal post; the time between an observation and the advice was approximately one week. Later on the data exchange was digitally.

The first developments for running these advisory models on the farmer’s pc failed, because there was a lack of surplus value compared to extension officers. Furthermore, the models were not adapted to the questions and needs of farmers. Farmers quickly learned the calculation rules of the models and used the rules in practice without using the models (Daamen, 1991).

ADVISORY SYSTEMS USED ON STAND-ALONE COMPUTERS AT FARMS, THE NEXT STEP TO DECISION SUPPORT SYSTEMS

In the mean time the development of a new generation of Decision Support Systems (DSSs) started: the weather-related DSSs (Bouma, 1993). These systems had a more integrated approach. Besides weather data, other factors important to the duration of protection were taken into account, such as: the development of new leaves, dose of fungicides, wash-off by the rain and irrigation, susceptibility of the cultivars and disease pressure in surrounding fields. Furthermore, new more powerful personal computers were introduced at farms and there was a development of on farm weather stations. Data of these weather stations, together with the weather forecast were used as input for the weather related models in the DSSs. From that moment on these
systems had an extra value: the most accurate advice was adapted into the current situation regarding disease pressure (actual and forecasted), fungicide covering and weather circumstances.

Another factor which was of main importance for the success of the DSSs was the governmental policy of most European countries to reduce the input of active substances, the number of applications and to reduce the dependency on chemical crop protection. Aim of this policy was to come to a more sustainable agriculture. One of the possibilities to reach that aim is the use of DSSs. Together with the establishing of the main DSSs, a number of models were developed to reduce the impact of the plant protection products in the environment e.g. PIEC (Predicted Initial Environment Concentration) (Gyldenkærne & Secher, 1996) in Denmark.

**MOST IMPORTANT DEVELOPMENTS OF DECISION SUPPORT SYSTEMS**

**NORWAY**

In Norway a bulletin board system was set up in the beginning of the nineties, some years later also a voice board system called TELEVIS was introduced. The bulletin and the voice board gave the results of the monitoring of diseases and pests in wheat and barley fields together with the results of NORPRE (a warning system for diseases and pests in barley and wheat), the two and five day weather forecast and the recorded weather data (Magnus et al., 1991, 1993). In 1995 the system was expanded with models in cereals, potato, top fruit and vegetables (Magnus, 1995). In 2001, a new web-based warning system was developed, called VIPS. VIPS calculates warnings for several pests in top fruit, vegetables and cereals. The warnings are site specific and the extension service validates the biological data (Folkedal & Brevig, 2003).

**FINLAND**

At the end of the eighties a development started to use GIS techniques for monitoring and predicting potato crop production (Merkkiniemi & Kaukoranta, 1991). By using the system it was possible to use maps to have an overview of the distribution of potato cyst nematodes and predicting its developments. The data could be analyzed with the climatic data, the type of soil and other biotic factors. Besides the GIS-system there were some expert systems for the use of herbicides, fungicide and insecticides, (Rantanen et al., 1993). Later on the GIS-system was used for forecasting and monitoring pests e.g. the carrot fly, (Tiilikala et al., 1996).

**DENMARK**

An advisory system for crop protection (PC-Plant protection) was developed in the beginning of the nineties (Secher, 1993). PC-Plant protection could be divided in two parts, a control part for pests and for weeds. In the weed control part, an expert model decides if weed should be controlled. The system selects the optimal herbicidal mixture and calculates the adjusted dose. This approach will reduce herbicide use to a minimum (Rydahl, 1993).

The pest part of the system calculates adjusted dosages of fungicides and insecticides by the use of weather related cereal pest and disease models. Besides, a decision support system for the control of potato late blight NEGFRY has been developed (Hansen, 1993). In 1996, NEGFRY was integrated in PC-Plant protection (Murali & Hansen, 1996).

Since the beginning of the nineties the quality of these systems has been improved by the use of a lot of research results. The Danish systems are also used in a lot of other Nordic countries as Sweden, Finland, the Baltic countries and Poland. Crop Protection Online, a new web-based system has been developed in 2001 (Hagelskjær & Nistrup, 2003, Rydahl, 2003). The system architecture has been designed with emphasis on a
high level of flexibility for future adjustments due to agronomic and legal requirements. The DSS models have been linked to a pest identification module and to a comprehensive database on label information on plant protection products.

THE NETHERLANDS

Since the middle of the eighties of the last century, Dutch farmers are using DSSs as an aid in the control of pests and diseases. It started with EPIPRE; later on, weather related potato late blight warning systems were developed (Prophy and Plant-Plus). In the nineties of the last century a lot of weather-based DSSs were developed. E.g. systems for the control of onion leaf spots; Mycos, a model for the control of ring spot in cabbage; different models for the control of blight fire in flower bulbs; different models for the control of scab in apples and pears (DLV-Welte en RIMpro); a model for Cercospora leaf spot in sugar beet and a system for the control of fungal diseases in winter wheat and barley (CerDis) (Bouma, 2003). More recent developments are the model for control of Botrytis in strawberry, downy mildew in lettuce, and a system for the guided control of nematodes (Nemadicide). Also a decision support system was developed to predict and to evaluate the effect of meteorological conditions on the effectiveness of the application time of pesticides (GEWIS) (Bouma, 2003).

In most cases the models were developed by private organizations (Opticrop and Dacom) in close cooperation with the organizations for applied research or together with the fundamental research institutes. Most models use the Internet for weather data exchange or transferring of renewed parts of the models.

UNITED KINGDOM

Since 1990 a number of models were used by farmers and advisors concerning diseases and pests in arable crops due to the developments of ADAS (the British extension service) and the METeorological office (Hims, 1991). Later there was a joint research and development program for developing a computer based DSS to produce on-going forecasts of risks posed by main pests and diseases in cereals and rape, IDR (integrated disease risk) and IPR (integrated pest risk) (Walters & Hims, 1993). Furthermore PEST-MAN, a computerized forecasting tool for pests in apple and pear was developed (Morgan & Solomon, 1993).

Potato Late blight DSSs were first introduced to the UK in the form of Beaumont periods (Beamont, 1947) in the 1950’s and was subsequently replaced by the Smith period (Smith, 1956), from 1975 up to now. Since the introduction of the “Fight against Blight” campaign there are some web sites, which provide information on late blight. These web sites, Blight alert and Blight watch, are based on weather based forecasting systems, (Bradshaw et al., 2004). In 1998 Plant_Plus (a Dutch Late Blight DSS) was introduced in the UK (Hinds, 1998) to produce farm specific advices.

The Morph/HRI group developed and introduced a software framework containing computer models called MORPH (Methods Of Research Practice in Horticulture). The results of MORPH models can take the form of tables, spreadsheets or graphs for interpretation by growers and consultant agronomists. The models can be divided into three groups: Top Fruit models (apple scab, powdery mildew, Nectaria fruit, fireblight, codling moth, tortrix moth and pear psyllid), vegetable/cabbage diseases (Alternaria, ring spot and white blister) and vegetable/cabbage pests (cabbage root fly, carrot fly, pollen beetle and narcissus fly).

DESSAC (Decision Support Systems for Arable Crops) is a combination of a set of databases and three modules of DSSs. The wheat disease manager, a system for decision support for oilseed rape pests, a system for weed management and a model for the simulation of nitrogen in arable land (Audsley et al. 2005).
GERMANY

In Germany a lot of weather related pest and disease models have been developed, but not in a structured way. At different universities, the same developments took place at the same time due to the fact that there was no federal responsibility for advices on crop protection in Germany. Important developments were Pro_Plant, the Bavarian and IPS approach, the models of the German Meteorological Service and models from the former GDR.

In 1993 the PASO-project started, 13 plant protection services from 11 Bundesländer were participating in this project. Ten agricultural and horticultural models were validated and used by the advisory services (Kleinhenz et al., 1996). To ensure the continuation of this work on DSS and the elaboration of new systems, an institution (ZEPP) was founded. Seven of ten tested DSS proved to be useful for crop protection extension work and also some new models were developed during the test phase and incorporated into the ZEPP work, (Kleinhenz & Rossberg, 2000). In 2000, ZEPP started to elaborate an internet-based warning system for the main arable crops. This system is based on weather based DSSs, comprehensive up-to-date monitoring in farmers fields, and specific advices from extension officers (Röhrig & Kleinhenz, 2002).

Pro_Plant (Frahm et al., 1991, Frahm & Volk, 1993) was developed to reduce the input of plant protection products to a minimum. In 1995, Pro_Plant covered cereal diseases, growth regulators in cereals, sugar beet diseases, rape pests and weeds in maize (Frahm et al, 1996). In 2001 the system was redeveloped to an internet version. The internet version (proPlant expert) gives online assistance for making field-specific decisions on a range of problems, e.g. fungicide application in sugar beet, cereals and potatoes, growth regulators in rape and cereals and insecticides in rape. On the other hand also the “old” CD-rom version can be used (proPlant Classic), (Newe et al., 2003). With help of the system it is also possible to generate maps (of Germany) of the possible infection of Phoma in oil seed rape (Volk & Alpmann, 2006).

In Bavaria the warning service for plant protection runs a system of DSSs and forecasting models for several fungal pathogens (cereals and potatoes) and pests. A network of weather stations provides the weather data necessary for the DSSs, (Tischner, 2000, Hausladen & Zinkernagel, 2002). Furthermore also models for the control of diseases in top fruit, grapes and vegetables were developed (Hoppmann & Holst, 1996, Hindorf et al., 2000, Leinhos et al., 2002).

SWITZERLAND

Decision support systems for winter wheat (EPIPRE) and winter barley (HORDEPROG) were used in Switzerland since the middle of the eighties. At the beginning of the nineties, a DSS for late blight control (PhytoFAP) has been developed (Forrer et al., 1991). PhytoFAP was the precursor of PhytoPRE, an information and decision support system for late blight in potatoes (Forrer et al., 1993). For the timing of the first spray, PhytoFAP used the “Negativ-prognose”-model. Later this model was improved with help of the Main Infection and Sporulation Period (MISP) model. The MISP model indicates weather events, which are crucial for the outbreak and development of late blight epidemics. Both models transferred into PhytoPRE+2000 (Steenblock et al., 2000).

In 2001, PhytoPRE+2000 was replaced by an internet version as a plot specific potato late blight recommendation system, (Steenblock et al., 2002).

Vitimeteo plasmopara is a warning model for downy mildew in grape and was developed between 2002 and 2003. The model calculates the possibility of sporulation, infection and incubation time. The model is used in the southern part of Germany and in Switzerland (Bleyer et al., 2006).
FRANCE

In France a number of forecast models were developed for diseases in cereals in the nineties of last century. Meteopro was developed as a model for decision support in vineyards against diseases and pests (downy mildew, grey mold, black rot and grape moth) (Maurin, 1991, Maurin & Fricot, 1993). Later a general approach was set up of a system of weather stations, together with field observations to run 28 forecasting models in top fruit (e.g. codling moth, apple scab, fire blight of apple, olive fruit fly), viticulture (e.g. downy mildew, grapevine moth), vegetable growing (e.g. Septoria apiicola), cereals (e.g. Puccinia triticana, Mycosphaerella graminicola), potatoes, oil seed rape and sunflowers (e.g. Potato late blight, Sclerotinia sclerotiorum, brown stem canker of sunflowers Diaporthe helianthi) (Jacquin et al., 2003)

ITALY

The developments of DSSs started on an early stage in Italy. In 1973, a project was launched starting with testing of IPM methods. In 1989 a computer network was installed to collect and process the data obtained from the farms and to supply meteorological data to the technicians. At that time there were also some developments of models for diseases in orchards and vineyards (Cravedi, 1990, Malavolta et al., 1991, Orlandini et al., 1993). In the Emilia-Romagna region there were a lot of developments of DSSs, e.g. a model for cereal diseases (Battilani, et al. 1993). Later on a number of models were developed such as for the prediction of: tomato late blight, onion leaf diseases, botrytis in strawberry flowers and fruits, grape downy mildew, Cercospora in sugar beet and also some pest models. These different developments showed the lack of a national project. The approach of the developments and also the management of the models and systems differs between the several regional warning services. The majority of the models were developed for the control of fungi and pests in: grapevine, apple, pear, peach, tomato, potato, onion, olive, sugar beet and wheat, (Rossi et al., 2000). Recently some simulation models have been developed, e.g. for the simulation of ascospores of Venturia inaequalis on apple trees (Rossi et al., 2003), for the risk of Fusarium head blight in wheat (Rossi et al., 2003), and for estimating the potential development of Diaporthe helianthi epidemics (Battilani, 2003).

ADVANTAGES OF THE USE OF DSSS

By using adjusted dosages of the best-suited plant protection product adapted to the actual conditions of disease pressure and meteorological conditions, the use of the DSSs can result in a lower risk of damaged crops by diseases and pests and, in a lot of cases, in a lower input of active substances.

The results of a large number of trials with DSSs in many countries has shown that in most cases, DSSs provides good advices on the applications of plant protection products and helps to reduce the input of active substances and to lower dependency on agrochemicals. By using these systems, users will be more conscious of the relation between weather circumstances and the efficacy of plant protecting products. In the meantime the systems has been established as an important tool for the achievement of a more sustainable agriculture (Bouma, 2003).

PERSPECTIVES

In the last years there were a lot of new developments. The introduction of the PDA was only one of these. A number of suppliers of DSSs offer also a “smaller” system to run on a PDA. PDA’s are equipped with GPS receivers and can carry geographical information like soil maps, topographical maps and other environmental
conditions. Together with actual weather data they facilitate site-specific applications of herbicides and pesticides. It is therefore an easy to use tool besides or in combination with the PC.

In a number of countries there are developments with GIS-applications. In the (near) future there is a possibility for implementing a number of the DSS-models in a GIS environment to support the precision agriculture by making adjusted spray advices based on plot specific circumstances. Recent developments of mobile communication technology and the Global Navigation Satellite System (GNSS) enables the development of precision farming and facilitates practical solutions that can be fit into practice.

Site specific information collected by sensors mounted on tractors and agricultural machinery will become important input in decision support systems. Weed detection systems using cameras and picture analysis offers great opportunities to improve selective spraying. Several studies have shown that the use of herbicides can be reduced significantly (35% - 90%), when product and dosages are applied adjusted to weed species and sizes.

**CONCLUSIONS AND FUTURE DEVELOPMENTS**

In the last years a lot of weather-related pest and disease models have been developed. Between the countries, there were a lot of similar developments from the first set up of the programs until providing the programs on the internet.

In the majority of cases the models lead to a good support of applications with agrochemicals and helped to reduce the input of active substances, lower the frequency of use and the dependency of agrochemicals. Furthermore, by using these systems the users will be more conscious of the relation between weather circumstances and the efficacy of plant protection products.

The weather-related decision support systems are an important tool to achieve a more sustainable agriculture. The systems are not designed to make an absolute decision, but instead they collate and process relevant information, interpret and communicate a range of suitable options to be used in the decision making process. Successful DSSs where those where the users were involved in the design from conception to delivery.

**NIEVEEN & BOUMA AGRO WEATHER SERVICES**

Recent work by the authors has resulted in a New Zealand agrometeorological web site called: http://www.agweather.co.nz. This site provides comprehensive information on crop weather, crop diseases, drying of grass, crop protection and the applications with agrochemicals to reduce the input of active substances, given the weather forecast. The authors are looking at expanding their work to other countries, such as: UK, Ireland, Australia, USA and South Africa. Feel free to contact us on this matter.
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