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FORECASTING — Scope and Problems

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Abstract

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The last decade showed a renewed interest for plant disease forecasts. The new concept of forecast is trying to combine classical type of forecasts together with rules for decisions under uncertainties on future events. It is mainly supported by the IPM concept of control measures. The scope of forecasting is enlarging, beyond spray timing into determining economic and control tresholds, dynamics and potential danger of pathogens and behavior of diseases. Development of forecasts require more accurate and sophisticated methods than the results themselves, which will depend largely on it. Actually electronic devices are improving data collection, analysis and widespread of results. Future trends will rely more and more on computers. To establish forecasting programs in semi-arid regions, monitering data should be accumulated, and care should be taken in testing the results validity.

Opinions about need, value and use of forecasting in crop protection are split at present. Some scientists or crop protection staff doubt whether there are enough valid forecasts to deal with them at all. Others use them and point out their economic and, more recently, also their ecological benefits. But still it cannot be denied that at least in Western Europe many operational forecasts have been discontinued during the past twenty years, mainly for two reasons:

(1) cheap pesticides and
(2) high production inputs which result in increased risk aversion amongst farmers.

On the other hand it is obvious that research has turned to forecasts again (Wause 2 Massie, 1975, shrùm, 1978). More and more relevant papers are appearing and specific conferences are organized to discuss progress and problems of forecasting. About half of the forecasts we have found in the literature for plant diseases have been published during the past decade.

A revival of forecasts ?

The comeback of forecasts and their likely further development will be supported by:

(1) the modern epidemiology which provides better insight in interactions between pathogen or pest populations and the crop under the influence of environment and human interference, and
(2) the development in monitoring techniques (e.g. pheromone traps), in computer science and technology, in electronics, in data processing.

But it appears that the notion of forecast will have to be wider than it used to be. Forecasts in crop protection comprise the **classical type,** like Van Everdingen's 'Dutch Rules', the Mills - Laplace table for apple scab, etc. plus all **rules for decisions under uncertainties** on future events. All forecasts are thus based on information (or opinions) on some incomplete ground. This by no means is stretching the concept of forecast too far. Forecasts always have predicted some future event relevant to crop protection. In fact, every rational person indulges in forecasting for his future action, and so does every rational farmer.

Obviously such wide usage of forecasts is required by, and in fact, in compliance with, the concept of integrated pest management (IPM). Each control (or treatment) threshold implies a pest or disease development which most likely will reach the economic damage threshold. Hence, an empirical or research -based control threshold in fact already is a forecast.

No doubt, it is IPM which will give a new boots to forecasting. IPM is an improvement of the present state of art in crop protection and not only a mere alternative to chemical pest control. IPM, however, requires decision making based on a given pest situation at any time in a particular field (or area). Forecasts should imply any technique, tool or even simple clues, e.g. growth stages of the host, in brief, everything that would facilitate prediction of a future event. Any forecast irrespective of its objective should be as simple as possible. For instance, forecasts for spray timing can be either

- simple visual criteria (e.g. growth stage of host, disease severity, pest density, trap catches), or events (e.g. Irish rules for potato late blight)
- simple summation of temperature, rainfall, or similar (e.g. Dutch rules for potato late blight)
- tables or charts
- mathematical equations
- computer models.

Scope of forecasting

What is the scope of forecasts in crop protection ? Spray timing in the future will not be the only objective for forecasting although it will always remain important. Forecasts not necessarily must reduce the number of sprays but make them more effective. This can be achieved when a forecast ensures the most susceptible stage of a pest to be hit. On the other hand, to avoid resistance amongst pathogens and pests the number of sprays should be minimum to reduce the selection pressure and help to protect beneficial organisms. Beyond spray timing, forecasting in crop protection has various and even intricate applications (table 1).

It is already feasible to forecast

- whether or not a certain pest or disease will exceed the economic threshold in the forthcoming season (in sporadic and marginal damage areas, sensu Weltzien, 1972)
- first date at which the control threshold will be reached, e.g. «negative prognosis»
- course of population development for various applications (e.g. for the determination of control thresholds as well as for risk periods)
- crop losses.

Table 1. Application of forecasts in plant disease control.

Forecasting	**Number of cases**
Spray timing	24
Disease progress	11
Disease occurrence (whether or not)	10
Negative forecasts	4
TOTAL	**45**

Desirable forecasts are those that would predict

- dynamics of pathogen races as essential information for strategies based on sowing resistant varieties
- potential danger from pests or diseases not yet occurring in an area as being important for quarantine and for areas with vulnerable crops
- behavior of diseases and pests when newly introduced, or when agricultural practices change.

All the forecasts quoted here as being already feasible have an application in the Integrated Pest Management (IPM). They are instruments for decision making under uncertainty. But their relevance in crop protection rests on the economic damage threshold which they are actually based on, or at least imply. For instance, a forecast which predicts the need to treat a pest in the forthcoming season permits the choice of seed dressing or a resistant cultivar, or similar. A negative forecast predicts the proper starting date of crop protection, spraying or other, and thus saves premature sprays or other activities. Negative forecast can be computerized, or simply in the form of disease and pest calendars. The former is based on specific experiments, the latter on record keeping over years by extension people, and its evaluation.

Some prerequisites for the use of forecasts

Forecasts are obviously irrelevant when

- a pest never exceeds the economic damage threshold, or
- when no means of control are available, or
- when treatment is cheap, or
- when a routine measure against other pests takes care of the problem.

Forecasts have little scope in high value crops. If, however, the EDT is exceeded, control possible and required, the feasibility of forecasting still depends on

- adequate and simple monitoring of parameters used as predictors. Adequacy is the degree a method satisfies its objectives, e.g. timing of the next spray round. Reliability is expressed as the consistancy of accurate forecasts.
- satisfactory accuracy of the forecast. Though forecasting according to Waggoner (1960) is «epidemiology applied with courage», or with tact and experience, a 80% level of correct forecasts should be strived for to satisfy risk aversion of farmers and crop protection staff.
- the notice of a forecast must not be too short to allow for an adequate reaction time of farmers or advisors, for the farm routine, and for the delays in communication.

Ideal forecasting methods are the ones that can be operated on farm or village level without expensive equipment or skilled professional staff.

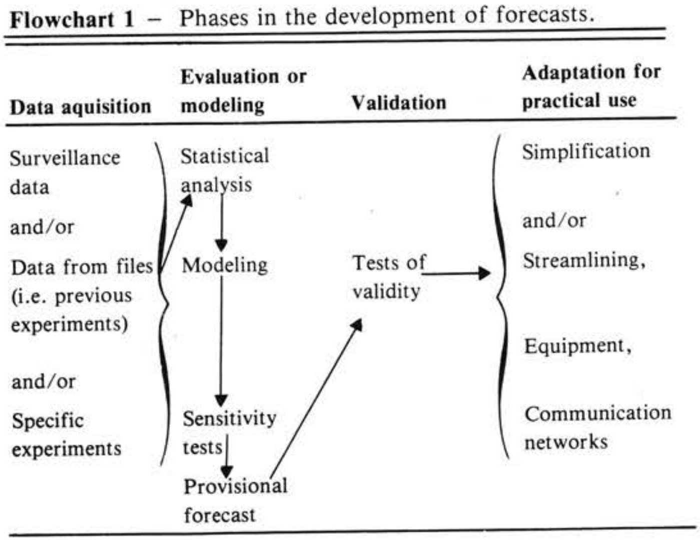
Some prerequisites for the development of forecasts

A forecast largely depends on the quality of data on which they are based, their proper analyses, and a thorough testing procedure.

Forecasts can be developed from surveillance data, appropriate 'historical' data, e.g. data in files, or specific experiments. Essential is a well defined objective for the forecasts to be developed. When developing forecasting methods this should be done within the disease or pest triangle, i.e. host, pathogen or pest, and weather.

Research for the development of forecasts will always be more sophisticated than the forecasts that eventually result for practical usage. Whenever feasible, factors from each of the angles of the disease/pest triangle should be considered equally well in the planning of the experiment, or in the definition of promising parameters. After analysis, however, only parameters from one or two of these groups of factors usually suffice for the purpose of a forecast. This procedure can be sketched as shown in the flow chart 1.

Flowchart 1 – Phases in the development of forecasts.



Basically forecasts can be based on criteria from

- the host biology, e.g. growth stages, crop age and its correlation with disease outbreak and development
- facets of biology or pests and pathogens, and states of disease or pest cycles (pheromon & light traps, egg counts, sporetraps, disease intensity, etc.)
- climatic and/or other environmental factors
- a combination of two or three of the above criteria.

It should be clearly understood that for the development as well as for the implementation of forecasts, so far only recorded weather parameters are used. Forecasts in crop protection still do not rely on weather forecasts although they imply a certain course or combination of weather events, e.g. as in the so- called Dutch Rules for potato late blight. They have shown the highest degree of correlation when a particular forecast was developed and tested. There is no need for any causal relation between one of these factors (predictors) and the predicted event.

Table 2 shows to what extent parameters of these groups and their combinations are actually being employed in forecasts of plant diseases.

Table 2. Number of forecasts for which predictors have been derived from either host, pathogen / disease, weather or a combination of such factors.

Predictor derived from	Number of case out of **46 forecasts reviewed**
Weather only	21
Host only	6
Pathogen or disease only	4
Weather + host	1
Weather + pathogen / disease	9
Host + pathogen / disease	2
Host + pathogen / disease + weather	3
TOTAL	**46**

Present developments in forecasting

Though in the past the unilateral reliance on weather parameters as predictors was considered to be a serious handicap they are gaining ground again. This is due to a better understanding of epidemiological implications and particularly new technology. But such weather parameters have to be used against the background of growth stage and available inoculum. This is also true for entomology. Here the concept of degree days is often used in relation to lifetables of insect pests and/or trap catches, the latter for monitoring. In this particular case computer facilities turned out to be very useful. In plant pathology microprocessors are available which are equiped with sensors for temperature, rel. humidity and rain which are measured (within canopy), and from data thus obtained microchips which are programmed to do the forecast.

Electronic devices can also be used for remote sensing including the use of satellites. This may favour some concentration of facilities and professional skill as well as the development of the communication network needed for warning systems. There are tendencies for centralized warning systems with a computer as the operational unit. Parameter values for the forecast can be provided by individual subscribers, observers, scouts, etc. over telephone or terminals, and - on-line or not - by remote sensing devices.

Specific problems for forecasting in semi-arid areas

Nearly all forecasts have been developed in areas where, after the start of an epidemic inoculum or pest density is mostly sufficent for an outbreak, which then are usually a function of weather parameters. Under semi-arid conditions and in irrigated crops the situation is even more complex. In contrast to temperate zones in semi-arid areas, size of inoculum is often of overriding importance and determines timing of disease appearance.

In addition, distinct differences may exist between seasons in the Middle East. In spring, diseases developing in winter can be carried by «inoculum in situ» (old crops, glasshouses, plastic tunnels) into seasons not very favourable in climate (May, June). Such mass of inoculum can compensate for adverse environmental conditions. Therefore, outbreaks of cereal rusts and onion downy mildew and other diseases occur. Especially favoured are diseases attacking winter crops in maturing stages like pea powdery mildew, *Alternaria* on potatoes and tomatoes, leaf spots on legumes during summer time. All this makes forecasts based on weather, pest and host parameters imperative.

In autumn, two distinct phenomena can be distinguished: There are diseases and pests which are abundant on summer crops and carried over into cooler months (October -November). (e.g. cucumber downy mildew and *Spodoptera* spp.). Diseases and pests of which the inoculum or density has been reduced over the summer (draught) behave differently. They need time to multiply during the favourable autumn months to get an epidemic going. Thus *Phytophthora infestans* on potatoes and tomatoes in the coastal plains does not appear before October and in the inland valleys not before November, provided the disease has first appeared in the Mediterranean coastal areas. Onion downy mildew does not show before the end of November, and the onion fly *(Hylemia)* not before early November.

In the latter cases, but also with diseases and pests during spring and summer, forecasting in your areas is often negative, i.e. defining disease-free periods. The determination of such regional threshold dates for date of outbreak of disease and pest in spring or autumn requires at least 10 years of observation and proper record keeping.

In consideration of such factors, calendars of disease occurrence can be drawn with due regard to date of sowing (zero-time) and the density of sowing as well as availability of initial inoculum. For instance, *Cercosporidium* on groundnuts comes a month earlier in fields in which groundnuts were also grown the year before. Also groundkeepers of onions can be a source for early downy mildew attack.

More difficult is the definition of factors affecting the timing of control actions once the regional threshold dates have been surpassed.

The definition of factors effecting spray timing in semi - arid regions must be based on knowledge of pathogen and host characteristics in relation to:

- leaf moisture - presence or absence of dew, irrigation by sprinkling or other methods during the rainless seasons, and precipitation, if any
- importance of shading as well as density of the crop, and weeds
- availability of inoculum and its rate of multiplication
- effects of host age on susceptibility.

Conclusions

The major problem with many forecasts so far is inadequate testing of their validity, i.e. whether they can be applied to the varying conditions under which a certain pest occurs. Hence, limitations and constraints of a forecast due to cultural practices, including irrigation (e.g. sprinkling or drip irrigation) and fertilizer use (N doses, timing, etc.), cultivars etc. should always be clearly known.

Many of the forecasts published have not been critically tried by other people. They rather prefer to develop their own ones. On the other hand, it is obvious that if there is a definite need and/or an organization behind a certain forecast testing, improvement and adaptation for its practical use is taking place, for instance, with forecast of wheat eyespot. In any case, a safe forecast needs years and many challenges to mature.

Another shortcoming arises if forecasts for several diseases and/or pests of a given crop are to be implemented in the same field. Nothing is known yet how forecasts in such a case would interact through the control actions they incite. Also the case that two different forecasts for one pest may complement each other, as the Hyre and Wallin rules in the potato blight forecaster BLITECAST have not yet been studied to an extent that would permit conclusions.

As a matter of fact, only a fraction of the forecasts are adapted for computer usage with obviously no on-line forecast yet. Practically all rules used to be paper-and-pencil rules and were later translated only into computer programmes. Only a minority of them are actually mathematical functions. Even so, they are mostly regression equations, some of them multiple ones. Any type of computer is suited to operate them. With increasing crop protection extension, need for the employment of computers will arise, e.g. if forecasts become elements of integrated pest management and data delivery systems.

Simulators as used in epidemiological research still have to be adapted to practical forecasting. At present they may, however, predict effects of certain actions and strategies in crop protection.

I shall finally make an attempt and suggest what could be done in semi-arid countries.

1. Set up and operate properly agrometeorological and trapping stations in farming centres
2. Record systematically dates of disease and pest appearance and subsequently the course of disease/pest development, noting carefully the growth stage or age of the crop, and the irrigation regime
3. Ensure adequate facilities for the evaluation of data thus obtained
4. Try to define as a step towards negative forecasting the disease / pest-free periods in each crop, i.e. the period duringj which monitoring does not have to be too intensive, and during which control operations are unlikely to be necessary.

الملخص

تجدد الاهتمام في تنبؤ امراض النبات، خلال السنوات العشرة الماضية. ان المفهوم الجديد للتنبؤ يحاول الجمع بين الطرق التقليدية للتنبؤ والقوانين التي تحكم تقلبات الاحداث المستقبلة. وهذا المفهوم مدعوم بفكرة المكافحة المتكاملة في وقاية النبات. بالاضافة الى امكانية توقيت المكافحة الكيماوية فلقد توسع نطاق التنبؤ الى تحديد العتبة الاقتصادية وعتبة المكافحة، وتحديد ديناميكية مسبب المرض وعلاقة ذلك بالضرر الذي يحدثه. ان تطور التنبؤ لظهور الامراض يتطلب طرق دراسية ادق واصعب من دراسة. والمعدات الالكترونية الموجودة حاليا تساهم كثيرا في تطور جمع البيانات، وتحليلها ونشر النتائج، وسيزداد الاعتماد على الكومبيوتر في المستقبل اكثر واكثر. ولاحداث مشروع تنبؤ للامراض في المناطق النصف الجافة، يجب تجميع البيانات اللازمة ثم اختيار مدى صلاحيتها في التنبؤ.

References

KRAUSE, R.A. & L.B. MASSIE, 1975: Predictive systems: Modern approaches to disease control. Annu. Rev. Phytopathology **13**, 31-47.

SHRUM, R.D., 1978: Forecasting of epidemics. In: HORSFALL, J.G. & E.B. COWLING (eds). Plant Disease. An advanced treatise. Vol. II. pp 223-238.

WAGGONER, P.E., 1960: Forecasting Epidemics. In: HORSFALL, J.G. & A.E. DIMOND (eds.) Plant Pathology. An advanced treatise. Vol. III. pp 291-312.

WELTZIEN, C.H., 1972: Geophytopathology. Annu. Rev. Phytopathology **10**, 277-298.