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Table of Contents

Page

Preface

This booklet gives an insight into research on integrated pest management problems at the German Federal Biological Research Centre for Agriculture and Forestry (BBA). The contributions were compiled on the occasion of a visit to the BBA by colleagues from the Agricultural Research Service of the United States Department of Agriculture from 30 October to 3 November 1995.

The US experts first visited the Institute for Plant Protection in Fruit Crops in Dossenheim and the Institute for Biological Control in Darmstadt. They continued to Braunschweig and Berlin.

The following articles are short versions of the contributions to a colloquium on integrated pest management held in the framework of that visit at the BBA branch in Kleinmachnow on 2 November 1995.

F. Klingauf

Integrated Pest Management in the Federal Republic of Germany - Concept, State, Problems and Future Development

FRED KLINGAUF and ULRICH BURTH

Looking at the development of crop protection in Germany in the second half of this century, one can easily make out different stages.

Spraying calendars dominated the first stage during the 1950's and 1960's. The second stage - the Good Agricultural Practice - has become today's standard. This stage developed quite rapidly during the 1970's because farmers clearly realized the economic advantage of saving plant protection products. In contrast to that, integrated crop protection as the third stage is only slowly gaining ground. The reasons are evident. Integrated crop protection brings only little economic advantage for the farmer. The main effect is to reduce the stress on the environment, which in fact is beneficial also for the farmer, but in the first place for society as a whole.

Although many farmers practice some methods of integrated crop protection, there is no reliable information as to how far integrated crop protection has gained ground in Germany. If one proceeds from the reduction of the application rate of active ingredients per hectare or per kg of product as a aim of integrated crop protection, there has been a very promising development over the past few years.

The application rate of active substances has decreased in Germany more rapidly than expected, nearly without the public being aware of it. This has various reasons:

- Germany was reunited in 1990. In this context, large sections of East Germany's agriculture broke down during 1990 and 1991 and were re-structured. The consumption of plant protection products declined sharply.

- The agro-political framework in the European Union has changed since 1992 (falling producer prices, in particular for cereals). This has clearly increased the farmers' willingness to use methods of integrated crop protection and reduce costs by lowering the consumption of plant protection products. A more purposeful application of plant protection products, with a closer view to economic injury levels, has led to a reduction of product application rates and prophylactic treatments (such as pre-emergence applications of herbicides). ZSCHALER et al. (1995) found out that the practical application rates remained already 24 % below the authorized application rates in 1991 and 1992.

- There is a continuous trend, in particular in herbicides, towards active substances which display biological efficacy already in minute amounts (for instance, sulphonyl urea compounds). Fitting into this trend is the substitution of racemates in some herbicides by the really active part of these substances, the optical isomers, which has nearly halved the application rate of active ingredient.

- Set-asides (1.6 mio ha, that is 9.4 % of the agricultural area, were set aside in Germany in 1994) and reduced growing of crops which require intensive pest control have also led to a reduction of the consumption of active ingredients. The potato-growing area in Germany decreased from 548 000 ha to 315 000 ha between 1990 and 1993. This has resulted in a considerable decline in the use of phytophthora fungicides.

- Finally, changes in the legal framework, such as bans (for instance on atrazine) or restrictions of use, have limited both the total use and the share of certain plant protection products in the total protectant use.

The concept of integrated plant protection dates back to the 1950ies and was a first critical response to the growing use of plant protection chemicals at that time. From the beginning of the Fifties, a growing number of publications pointed out the effects of plant protection products on the biocoenosis. Publications by COLLYER (1953), PICKETT and his team (1953) and RIPPER (1956) were then the most comprehensive works about different products' effects on beneficials. Similar investigations started in Germany in 1954 (STEINER, 1962). They did not, as it would be suspected today, proceed from aspects of protecting operators, consumers or the environment, but from the knowledge that the use of plant protection chemicals cannot achieve durable success without taking due account of the biological interactions. In 1959, the International Commission for Biological Control (C.I.L.B.) founded a 'Working Group for Integrated Plant Protection in Orchards' led by de FLUITER. STERN et al. (1959) describe the integration of biological and chemical measures in an 'integrated control concept'. At that time, the concept of integrated plant protection is mainly relevant to intensive-type fruit plantations because of massive problems with spider mites there (MATHYS, G. and BAGGIOLINI, M., 1964; STEINER, 1975). Its aim is the defence against pest organisms.

A first definition of integrated plant protection, which is generally recognized and still applied, dates from 1964:
"Integrated plant protection is a technique which uses all methods acceptable under economic, ecologic and toxicologic angles to keep pest organisms below the economic injury level. Its principal tools are purposeful utilization of natural control factors and preventive measures."

The aim is to fend off damage while making the most possible use of non-chemical measures. This must be seen against the background of serious problems in practical crop protection arising with the development of resistance against insecticides and acaricides.

Later definitions reflect the changes the concept of integrated plant protection underwent in the following years. The farmer's view, which aimed at solving problems in practical crop protection, lost more and more influence, while the demand to protect operators and consumers, and above all the environment, by least possible use of chemicals came to the fore.

Accordingly, the legal definition (Article 2 of the German Plant Protection Act) is:
"Integrated plant protection shall be a combination of methods in which, with particular attention being paid to biological, biotechnical, plant-breeding and cultivation-related measures, the use of chemical plant protection substances is limited to the necessary extent."

The definition used in the European Union (Council Directive 91/414/EEC), which was published five years later, sounds similar but reflects current environmental concerns by sharper formulations in details:
"Integrated control:
the rational application of a combination of biological, biotechnical, chemical, cultural or plant-breeding measures whereby the use of chemical plant protection products is limited to the strict minimum necessary to maintain the pest population at levels below those causing economically unacceptable damage or loss."

Apart from the sharper restriction of the use of chemical plant protection products (necessary extent --> strict minimum), the criterion for that use is the arising otherwise of an economically unacceptable damage or loss.
The terms of 'integrated plant protection' and 'good plant protection practice' should not be considered as synonyms or mixed up. The 'good plant protection practice' is being developed by the European Plant Protection Organization and is meant to effect an economical, safe and efficient use of plant protection products, in particular by adherence to special guidelines. The concept of integrated plant protection includes good practice of plant protection, but goes clearly beyond it by consciously using natural control factors and mechanisms of biological self-regulation. In its principles of good plant protection practice, EPPO points out the difference between the two terms: "... integrated pest control... sets a different standard from GPP and this is also the EPPO concept. ... Practices which are not IPM can still be GPP, and the terms GPP and IPM should not be considered synonymous" (Anonymous, 1994).

More than three decades after its introduction, integrated plant protection is still putting high demands on science, extension services and the agricultural practice. We notice a development which is leading from separate strategies in the framework of integrated pest control to complex approaches on the farm level, and thus to integrated crop production. We also notice a growing need for practicable strategies which can be handled by the farmer and which are suited to ease the natural balance. It is obvious that such strategies can only gradually be achieved, depending on the progress of knowledge and agrarian politics.

In Germany, the Plant Protection Act of 15 September 1986 demands that principles of integrated plant protection shall be considered.

How far these principles are followed is up to the farmer. He may practice them partially only for economic reasons. In general, there is only little freedom of choice as to growing systems or the organization of crop rotation, and there is only a small number of practicable biological and biotechnical measures of crop protection which could be preferred to chemical ones.

Fruit and wine growers and horticulturalists have found a good way of developing and practicing integrated plant protection. In particular in fruit-growing, integrated methods have gained wide acceptance in Germany. They have been tested and found to be practicable, and are accepted by both growers and consumers. Integrated plant protection is practiced on a voluntary basis by growers who follow guidelines worked out by regional growers' associations and strictly supervised for adherence. The regional guidelines are based on general principles, minimum requirements and guidelines for integrated production of pome fruit in Europe which are adopted jointly by the International Organization for Biological and Integrated Control (I.O.B.C.) and the International Society for Horticultural Science (I.S.H.S.). The aim is to profitably produce high-quality fruit while preferring ecologically safe methods which minimize the use of agro-chemicals and the occurrence of undesired side-effects. This is to the benefit of the environment and human health.

Such regional guidelines for integrated plant protection will also be needed in arable farming. An old problem, which is still topical in Germany, is to demark integrated plant protection from conventional plant protection or alternative methods. Demarcartion from ecological farming is relatively easy, because alternative crop protection as it is practiced in ecological farming does not use any synthetic plant protection products. All other methods are used in both systems. The actual problem is to distiguish between a good practice of conventional plant protection and integrated plant protection, which must offer solutions not only for extensive farming, but for all sites and types of management, including intensive ones.

That demarcation between integrated plant protection and conventional methods must be accomplished if agriculture wants to credibly convey its striving for an environmentally gentle, sustainable land management for the future. Moreover, the mixed and unclear criteria frustrate any attempt to get information about to what extent methods of integrated crop protection are already used in agriculture.

The principles of integrated crop protection are not very helpful as criteria for the definition of integrated crop protection from conventional crop protection. They are partly identical with the standards of good agricultural practice, such as the demand for using appropriate cultural measures. Nor do they answer the question of how to rate a farm which cannot, or only to some extent, follow one or more of these principles because of economic constraints or because of some special management decision. This is the case for nearly all farms.

As a result of a discussion of integrated crop protection in arable farming in Germany, we have formulated requirements which are based on the principles of integrated crop protection and take account of all measures available for farms (BURTH et al., 1994). They say that a farmer practices integrated crop protection if he

1. applies a variety of cultural measures,
2. monitors the situation of infestation,
3. uses individual, non-chemical measures to prevent damage,
4. uses chemical plant protectants economically and with precision, on the basis of threshold values, and
5. makes use of extension services and further training.

To 1: Application of a variety of cultural measures
Among the cultural measures, crop rotation and exploitation of varietal resistance are of outstanding importance for integrated crop protection. The crop rotation, however, is particularly influenced by economic constraints. Still, one requirement is that crop shares in the rotation are designed so that there is no additional phytosanitary stress which would require additional pest or disease control measures. For that, it is necessary to define maximum cropping concentrations for different cropping regions. Highly susceptible varieties must not be grown in infested areas, if less susceptible, suitable varieties are available.

To 2: Monitoring the situation of infestation
There is a number of more or less expensive methods of monitoring the crops for pests, beneficials, diseases and weeds. Most of them are not yet well practicable. It should be the aim to enable the farmer to monitor and assess the situation of infestation in his own fields on the basis of warnings and forecasts by the crop protection services. Documenting infestation data, in as simple a manner as possible, makes sense in particular for the monitoring of weeds.

TO 3: Use of non-chemical measures to prevent damage
If the situation of infestation calls for protective measures, non-chemical methods should be considered first. Unfortunately, only very few protective measures are suited for arable farming, apart from mechanical weed control. In some cases, growing catch-crops will help to reduce the infestation with nematodes or to suppress weeds. Predators may also provide some biological control (Trichogramma against corn borer, promotion of predatory birds against field mice). Suitable non-chemical and alternative methods are urgently needed and are a permanent challenge to researchers.

To 4: Use of chemical plant protectants economically and with precision, on the basis of threshold values

The precise and economical use of plant protection products on the basis of threshold values is an essential part of integrated crop protection, and indispensable for arable farming in the foreseeable future. The demand to consistently apply the threshold principle as the basis for deciding on the use of plant protection products must allow for individual regional and site conditions. Moreover, threshold value concepts must be practicable by farmers. The first, most simple step would be that they provide a method to check whether at all a harmful organism is present in the field. Prophylactic treatment is only allowed if precise measures are not possible. If the use of a plant protection product cannot be avoided, the next step is to consider treatment of partial areas only, and to choose and dose products according to the situation. Selective products which spare beneficials must be preferred to widely active products, which should be avoided, and active ingredients should be changed to prevent the development of resistance. A record should be kept for later analysis of the reasons for control decisions, the measures carried out and the results achieved.

To 5: Use of extension services and further training

It goes without saying that a farmer who is facing such ambitious tasks must use all opportunities of official services and of training in the field of integrated crop protection. On this basis it should be feasible to define criteria which mark integrated crop protection in all kinds of sites and farming practices.

A first proposal is to define **three developmental stages of integrated plant protection:**

1. minimum requirements which can be fulfilled by every farmer,
2. application of all methods of integrated plant protection currently practicable, and
3. advanced integrated plant protection.

With every stage, the system gets more demanding, but also more venturous. Ecological effects gain more importance. The economic effects for the farmer vary, too. While the first stage can be realized largely without additional cost, the second stage includes some special measures, which should be promoted by special funds to compensate for farmers' losses. At the third stage, the farmer may suffer income losses in traditional fields of production, which he must try to compensate by new sources of income. Every stage brings a new reduction of the use of plant protection chemicals, relieving the natural balance step by step. This entails more extensive farming, which is a topical demand.

Example of minimum requirements of integrated crop protection in winter wheat

The following points, together with advise by official services, could provide a guideline to farmers to come up to the minimum standards of integrated crop protection:

1. growing of wheat by good agricultural practice,
2. regular use of warnings and recommendations by official extension services,
3. no use of varieties whose susceptibility is rated 7-9,
4. monitoring infestation:
   weeds: once during growth stages (EC) 13-29, assessing the infestation (species, stage, estimated density),
   foliage diseases: repeatedly during EC 29-61, counting 2 x 25 leaves and ears per field,
   cereal aphids: once at EC 69, counting 2 x 25 haulms per field,

5. control decisions based on threshold values:
   weeds: situation-related and regionally tested threshold values,
   foliage diseases: regionally tested threshold values,
   cereal aphids: 3-5 individuals/ear and leave at EC 69,
6. further necessary crop protection measures strictly by official advice,
7. no application of products which are very harmful to beneficials, such as pyrethroids or pyrazophos fungicides, to spare beneficials and indifferent arthropods,
8. documentation of all infestation and the crop protection measures taken.

Development of IPM needs improvement of the actual methods and techniques of integrated crop protection. Often, provided methods are rather impracticable, too expensive and of so low efficiency that the farmer faces a hardly calculable risk. This will let him resort to conventional methods - normally plant protection chemicals - the application, cost and effect of which he knows.

A particularly critical point for farmers is to make control decisions on the basis of threshold values, which is a central point of integrated crop protection. The problems start with crop monitoring. Important weeds and their distribution in the field are known to the farmer. The early detection and correct diagnosis of pests and diseases already present greater difficulties. Finally, farmers are hardly prepared to watch the development of infestation over a longer period and wait with control measures until a threshold value is reached. Although threshold levels have been worked out for the most important diseases, pests and weeds, farmers seldom use them for taking control decisions. Apart from the time-consuming and very involved procedure of monitoring the crops and determining the threshold level, farmers are most discouraged by the higher risk of yield and quality losses. Because, even if the threshold level is determined correctly with the help of warnings and forecasts by official services, the risk is obviously greater than if the mere presence of a pest triggers control measures, as it is the case on most farms. So, if the concept of integrated plant protection is to gain ground in arable farming, it is necessary to find simpler methods of determining threshold levels and making control decisions, and reduce the risks for farmers.

There are different possibilities of risk reduction which should be taken into account in research:

- more consideration of site conditions and farmers' experience with the occurrence of diseases, pests and weeds,
- improvement of weather forecasts,
- improving the knowledge about interactions among the course of infestation, crop resistance and tolerance, and the effects of crop protection measures, and integrating this knowledge into the concept,
- situation-related dosing of plant protection products,
- recording and exploitation of beneficial efficacy.

The stated deficits in the implementation of integrated crop protection in arable farming are starting points for research, which is focussing on the following aims:

1. Better use of the potential of biological self-regulation And of cultural control factors, including

   - biological control of pests and and determination of beneficial thresholds,
   - effects of field structures and natural field margins on the population dynamics of beneficials and pests,

- incorporation of cultural measures in the defence mechanisms.

2. Methods providing for flexible use of plant protection products according to the situation.

3. Development of alternative defence measures, such as

   - induced resistance,
   - biological methods, employment of antagonists,
   - physical methods (UHF technology, low-energy electrons),
   - transgenic plants.

4. Schemes of integrated crop protection for different degrees of farming intensity and for different practical conditions, including research to

   - construct a compendium of integrated plant protection,
   - integrate elements of integrated plant protection to yield strategic approaches for individual crops,
   - define the basic conditions for integrated crop protection in different sites and modes of land management,
   - assess the economic and ecological effect of integrated crop protection in arable farming.

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Integrated Control of Plant Parasitic Nematodes by Exploitation of Crop Plant Resistance

JOACHIM MÜLLER

Almost all agricultural and horticultural crops grown in Germany are attacked by parasitic nematodes. Most important are cyst nematode species in potato, sugar beet and cereals, root knot nematodes in vegetables and ornamental plants, stem nematodes in agricultural crops and herbaceous perennials, and migratory root nematodes mainly in nursery plants. The cyst nematodes are a permanent problem all over the country, whereas losses from the other species are reported only from restricted areas.

Control of the potato cyst nematode is regulated by national and European legislation, integrated control methods are only partially applied. The next important species, however, the sugar beet cyst nematode (*Heterodera schachtii*), is a good example for an integrated crop protection system which is successful and accepted in practice.

Integrated control methods should be adapted to the biological and ecological characteristics of the nematode species in question, and for *H. schachtii* eight components are considered to be relevant:

Population thresholds: This is the basis for integrated control methodology. However, routine methods for population assessment used by extension services are incapable of giving reliable results. Predictions of yield losses based upon economic thresholds are questionable. More reliable population estimates for improved yield prediction are possible, but are not economically justifiable at this time.

Natural enemies (antagonists): These are widespread and important, but have not been demonstrated to be useful for active control of the nematode.

Targeted applications: Broadcast nematicide treatments are normally used instead of targeted applications to patches of infection because nematode distribution is unknown or the appropriate technology is not economical. In Germany, no soil fumigant is registered for the control of *H. schachtii*.

Selective pesticides: Pesticides which are selective and non-toxic to beneficial organisms are not commercially available. Available nematicides are relatively non-specific in activity. If selective pesticides were to be considered, knowledge relating to the side effects of plant protection products on beneficial parasites and predators would have to be extended. At this time, no nematicide for application in sugar beet is registered in Germany.

Cultural practices: Early sowing can be recommended, but trap cropping is too risky. Intercropping of sugar beet with resistant radish has given negative results.

Rotations: Growing sugar beet one year in five would be an effective control measure but this is not economically practical.

Resistance in sugar beet: So far, breeding has not produced commercially acceptable cultivars that are resistant to the sugar beet nematode.

Resistance in green manure crops: There are disadvantages with each of the seven above-mentioned components for integrated control of *H. schachtii* and therefore a new approach to control was required. In Germany the growing of resistant green manure crops in sugar-beet/cereal rotations has produced promising results. Attack by *H. schachtii* is of no economic importance in these cruciferous crops, and breeding for resistance does not aim at preventing damage. As resistant sugar beet cultivars are not available, the new approach is to reduce sugar beet cyst nematode populations in a long-term rotation system using other sources of resistance.

The resistance was found in wild forms of oil radish (*Raphanus sativus*) and white mustard (*Sinapis alba*). Like all cruciferous species, these plants produce root exudates having a specific hatching stimulus for the encysted juveniles of sugar-beet cyst nematodes. The nematodes hatch from the eggs, penetrate into the plant roots, and become sedentary. In susceptible plants a nutritional cell develops now and serves as feeding site for the nematode. In resistant plants, however, the nutritional cell is induced, but breaks down after several days. As a consequence, only male juveniles develop and the nematode population decreases. In field conditions an average population decrease of 60 - 80 % can be expected with cultivars classified as highly resistant.

The Biologische Bundesanstalt is responsible for the testing of crop resistance to plant pathogens. 13 oil radish and 11 mustard cultivars were listed as resistant in 1995. They are grown either as catch crops following winter barley or in a set-aside programme all over the year. In addition to nematode control they increase soil fertility, prevent leaching of nitrogen and reduce soil erosion. After 15 years of experience from field trials, the beneficial effect of resistant oilradish and mustard varieties is well established. In Germany they are regularly used in rotations where *H. schachtii* causes problems and they are an essential component of integrated control systems for this pest.

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Simulation and Decision Models in Practical Crop Protection

VOLKMAR GUTSCHE and DIETMAR ROßBERG

General Situation

Computer-supported decision aids in plant protection are aimed at the following issues:

- diagnosis;
- forecasting;
- decision-making on control;
- impact of plant protection products on the environment.

They are based on results from scientific investigations and experiments, experience of plant protection extension service and mathematical simulation models. The euphoria which has grown with the rapid development of personal computers over the last 5 to 10 years has given way to a certain disillusion,

- because excellent interfaces often contain poor contents;
- because neither has the target group of the software (farmers or consultant) clearly been defined nor have their wishes been taken into account;
- because data input requires a considerable amount of time from the user; and
- finally, because a market for that plant protection software has not yet grown and implementation into practice is hardly possible without state funding.

In the following we present 3 comprehensive systems which may have the greatest chances of practical use in Germany.

Wheat model and barley model Bavaria

The system was developed at Universität München-Weihenstephan in collaboration with the Bavarian Institute for Soil and Plant Cultivation (Bayrische Landesanstalt für Bodenkultur und Pflanzenbau). The name 'model' is not quite correct, because it is not a mathematical model of cereal development but a system of threshold values of the most important diseases on wheat and barley such as: *Pseudocercosporella herpotrichoidis*, *Erysiphe graminis*, *Puccinia striiformis* and *P. secondita*, *Septoria tritici* and *S. nodorum* as well as *Drechslera tritici-repentis*. The employment of this systems requires field observations from DC 30/31 onwards 4 - 6 counts at a 10-day interval. 30 randomly distributed plants are checked for infection visually or with the help of simple aids (magnifying glass, staining). The resulting percentage is compared with a threshold value.

Decision-making is also based on general weather forecast and information of regional infection monitoring (available via videotex). The system requires a considerable service in the form of consultations and student assistance.

Advisory system PRO PLANT

It is a real expert system which was developed at Münster University (Universität Münster) in collaboration with the plant protection service of the Agricultural Chamber Westfalia-Lippe (Landwirtschaftskammer Westfalen-Lippe). It is used to control fungicide application to cereals and sugar beet, herbicide application to corn, insecticide application to rape as well as the application of growth regulators to cereals. The system is based on knowledge and experience of the plant protection service and simple model concepts on the effect of weather, cultivar, and fertilization on the development of infections.

The system contains a field data base, a weather data base and data bases with plant protection products and cultivars. Necessary weather data are aggregated daily data (air temperature (max., min., daily mean), relative humidity, daily precipitation, daily duration of sunshine, mean air temperature at a height of 20 cm) which are available either via videotex or are provided by specific agrometeorological station.

Employment of the systems requires in most cases a simple assessment of infestation or infection. The user is led through the whole period of crop development in the field. Finally, he obtains 'infection-related' decisions on plant protection products. If possible, reduced application rates are recommended. An information part of the system offers interesting parameters (e.g., content of active ingredient, application rate, price of plant protection product, cultivar susceptibility) for farmers and consultants and a first collection of colour photos of the selected pest.

Forecasting system PASO

The system integrates under a unified user-computer interface forecasting models of several universities and of plant protection research of the former GDR. These are models from arable farming and fruit and vegetable growing: SIMCERC (*P. herpotrichoides*), SIMPHYT (*P. infestans*), SIMERY (*E. graminis*), RHYNCHO_OPT (*Rhynchosporium secales*), SIMSIT and LAUS (*Sitobion avenae*), SIMLEP (*Leptinotarsa decemlineata*), BBA-DELIA (*Delia brassicae*), BBA-PSILA (*Psila rosae*) and EURO-BUGOFF (*Cydia pomonella*).

The system is partially based on comprehensive simulation models simulating dynamics of infection and infestation according to weather, fertilization, cultivar etc. Many models give both regional and field-related predictions.

The necessary weather data are temperature (2 m, 0.2 m), relative humidity, soil temperature, wind speed, precipitation and leaf wetness, partially as hour values. It is remarkable that some models do not require an observation of infection or infestation. Weather data are available via telephone modem from German Weather Service (Deutscher Wetterdienst) (at present test phase from project headquarters) or are provided by an agrometeorological station. At present the forecasting system is tested nationally with plant protection services of 13 Bundesländer.

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Injury Thresholds as a Basis of Control Decisions

BERND FREIER, BERNHARD PALLUTT, MARTIN HOMMES and PETER NIEMANN

All over the world, monitoring of harmful organisms and injury thresholds are considered to be decisive instruments of integrated pest management. The concept of injury thresholds contributes much to the purposeful and economical use of chemical plant protection products. For this reason thresholds have been in the centre of applied plant protection research in Germany for a long time.

The concept of thresholds is based on the infestation-damage relation, i.e. the relation between intensity of crop infestation and the damage to the farmer. It can be used to derive injury thresholds and economic thresholds. The farmer, however, is primarily interested in control thresholds. They can correspond with injury thresholds, as it is the case with weeds. However, harmful insects and fungi mostly show considerably lower control than injury thresholds because they have to anticipate the critical intensity of infestation.

Germany scientists, especially at universities and at the BBA, have been working on threshold concepts in arable farming for about 25 years. A lot of important works originate from the former Institute for Plant Protection Research in East Germany. So far scientists have determined approximately 150 thresholds for 74 harmful organisms and weeds in arable farming. Research into thresholds is concerned with three major issues:

1. Elaboration of **monitoring methods** with the help of **sampling theories**;
2. Elaboration of **infestation-damage relations**; and
3. Definition of **control thresholds**.

Monitoring methods should be as easy and safe as possible for farmers and consultants. A practical problem is that a somewhat representative determination of infestation requires an appropriate sample number. A minimum sample to determine the density of cereal aphids on a wheat field, for instance, comprises 73 stems. The method to determine the percentage of infested plants, the frequency of infestation in %, appears to be very practical. However, this method is always less accurate than the determination of average density. Another problem is the time needed. A monitoring for animal and fungal pests or for a group should not take more than half an hour per field. This time, however, is not sufficient for weed monitoring with a counting frame (0.1 m^2). One field requires 10 to 40 evenly distributed samplings to obtain a representative overview of infestation and to apply partial treatment if possible.

Research into infestation-damage relation is time-consuming scientific work. As a rule infestation-damage relations are not linear and depend on many factors. Relations appear to be especially complicated for weeds. Infestation-damage relation has to take into account for instance the different development of the individual weed species. For this purpose we have determined competition indices for the most important weed species in cereals. But there are other criteria like variety, date of sowing, fertilization and crop density.

The determination of control thresholds for farmers on the basis of infestation-damage relations and injury thresholds has to take into account in case of harmful fungi and insects population development because control thresholds have to refer to the beginning of infestation and infection. But the development of infestation depends on various conditions, especially weather, and is often difficult to predict.

This is the reason for an increasing propagation of **flexible, situation-related threshold concepts** and the testing of several harmful organisms over the last years. Besides biological, ecological and plant cultivation aspects a flexible approach can include also economic aspects. This is very clear from weed management. Furthermore, it has proven useful to take into account after-effects of weed growth in crop rotations. This leads to long-term thresholds. The Federal Biological Reserach Centre for Agriculture and Forestry has been concerned with flexible approach in three areas:

- cereal aphids in wheat;
- harmful lepidoptera and aphids on cabbage; and
- weeds in cereals.

The control threshold for the English grain aphid (*Sitobion avenae*) in winter wheat can vary between 1 and 10 individuals per stem at present DC 69 according to weather and beneficial organisms.

The control threshold for harmful lepidoptera (*Mamestra brassicae, Pieris rapae, Plutella cylostella* etc.) on head cabbage varies between 5 and 50 % infested plants according to infestation period, marketing goal and market situation between.

Weed management in cereals is already provided with comprehensive algorithms for a situation-related, flexible approach to control and economic thresholds.

Although we have a considerable scientific knowledge of control thresholds for numerous harmful organisms in field crops, there are still a lot of gaps and questions, for instance questions concerning the tolerance of field crops. Weed aphid infestation can even stimulate wheat yield. But it becomes obvious that the hesitative acceptance of threshold systems is not primarily a problem of insufficient or inaccurate thresholds. The by far bigger problem is the implementation of recommendations into practice. Many farmers seems to shun the necessary risk for threshold concepts. They often lack detailed knowledge, experience and time. Therefore, consultations must be part of the implementation of thresholds. In Germany, plant protection advisory service including recommendations on monitoring and thresholds is provided by the 16 Bundesländer. This service, however, does not contain on-site recommendations for farmers. Consequently, new forms of consultations in arable farming must be provided. On the other hand the threshold concept has to be completed by computer-supported decision aids as prediction and expert systems.

Finally, it must be stated that a situation-related threshold concept and, of course, integrated plant protection in general cannot be implemented in practice without consultants.

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Flexible, Situation-related Dosage of Pesticides

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Adjustment of dose rates of pesticides

The implementation of integrated pest management in practice makes it necessary to restrict the application of pesticides to the amount necessary taking into account biological, biotechnological, plant breeding and agricultural measures (legal definition of integrated plant protection according Plant Protection Act). This includes also the purposeful application of plant protection products according to threshold values and the adaptation of dose rates.

As a rule the authorized dose rate of plant protection products is high enough to guarantee also under worst case conditions sufficient action against harmful organisms. Consequently dose rates are too high under more favourable conditions for control measures. This gives the opportunity to vary, i.e. to reduce, the pesticide dose rate in relation to the situation without reducing action. The adjustment of dose rates and the use of thresholds enable the reduction of pesticide application required for economic and ecological reasons.

Herbicides

Pesticide application is dominated by herbicides with about 50%. Thus, a reduction of herbicide rates can yield striking benefits. The most important criteria for the determination of herbicide rates are:

- stage of weeds;
- weed density;
- weather conditions (e.g., temperature, relative humidity);
- competitiveness of the crop in the field;
- farming and cultivation system (e.g., conservation tillage); and
- addition of additives or ammonium urea solution.

Another point is the composition of the weed flora, i. e. the present species and their proportion in the whole weed infestation. This is an important criterion for the selection of a herbicide. It is not only the susceptibility of smaller weeds which allows to reduce dose rates, but also the competitiveness of the crop in the field. The most important criteria are:

- cultivar;
- seed density;
- N fertilization;
- preceding crop or crop rotation; and
- row width.

The influence of these interacting factors was studied in several years' trials and in long-term experiments at several sites. A few selected results are presented in Tables 1 and 2.

Table 1: Increase in yield (dt/ha) depending on seed density, N fertilization and intensity of herbicide application to cereals (average 1993, 1994, 1995).

Seed density (%)	N fertilization (%)	Intensity of herbicide application 2 x 25 %	25 %
100	100	4.4	3.9
100	50	8.4	5.5
50	100	6.7	4.8
50	50	9.8	6.1

Table 2: Increase in yield (dt/ha) depending on farming system and herbicide dose rate applied to cereals (WB, WW, TC) (average 1994 and 1995).

Farming system	Soil cultivation	Herbicide dose rate (%) 100	25
Forage growing (50% cereals)	Ploughing	4.6	4.2
	Conservation tillage	9.1	7.0
Crop farming (75% cereals)	Ploughing	16.4	14.2
	Conservation tillage	17.6	13.7

The results show that, in general, the greater competitiveness of the cereal crop due to better growing conditions allows a reduction of herbicide dose rates.
The authorized dose rates of foliar-acting herbicides can be reduced as follows and by the following amount:

1. Treatment at cotyledon to 2-leaf stage of weeds - 50-75%.
2. Dominance of weeds which are easy to eliminate - 50%.
3. Weed density around the threshold value - 50%.
4. High competitiveness of the cereal crop in the field - 25-75%.
5. Addition of additives or ammonium urea solution - 30%.
6. High relative humidity and short duration of sunshine before treatment, but high temperature and intensity of sunshine during application or immediately after it - 25%.

It is very rare that all criteria apply. But it is often possible to reduce dose rates by 50%. Under several conditions dose rates can be reduced by 75% without any risk for the farmer.

Fungicides

Efforts to reduce fungicide application to cereals started in the '80s with purposeful control measures on the basis of economic thresholds. Under this concept control measures are only applied when an infestation or infection is expected to cause economic damage. They are not meant to eradicate harmful organisms but to reduce the population to a range excluding economic loss. Over the last years individual treatment has become subject of critical examination and search has been made for criteria to adapt dose rates to the actual infection of the crop.

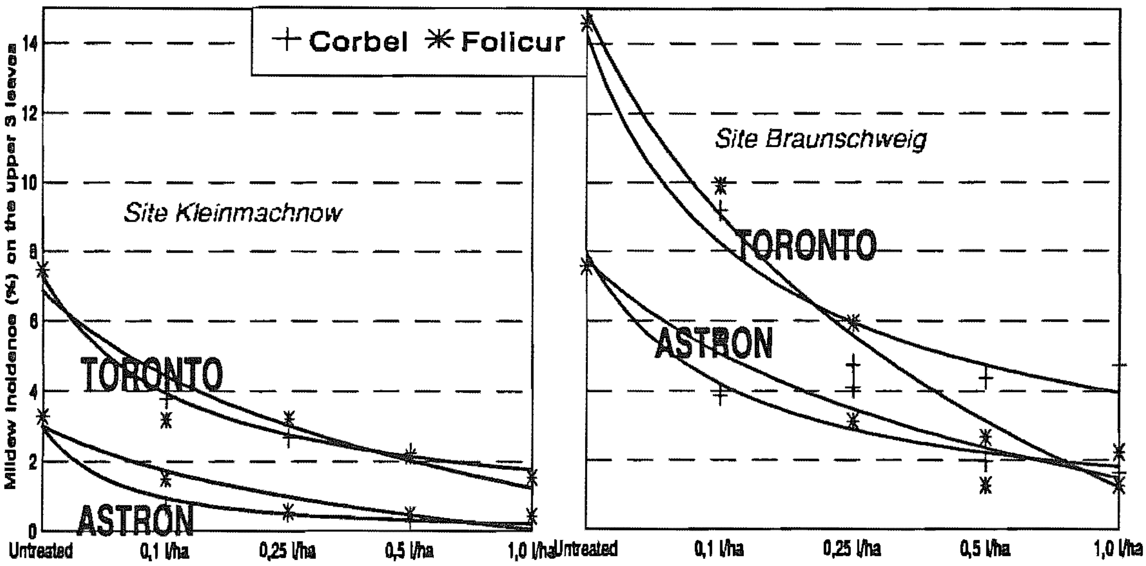
As a consequence general dose rates with the risk of reduced activity can be avoided. Important decision criteria to vary dose rates are:

- weather conditions;
- regional conditions for the occurrence of the disease;
- infection situation/infection pressure;
- size of plant surface to be protected;
- resistance of cultivars; and
- profile of action of fungicides.

Relevant investigations were performed on winter wheat, primarily for powdery mildew. The results show the effect of two fungicides at two different sites (Figure). In general, the regional disease risk decisively influences intensity of infection and effect of fungicides. Great importance is also attached to the susceptibility of cultivars; reserve action of fungicides is always lower for the more susceptible cultivar than for the less susceptible cultivar. The effect of more efficient fungicides does not reduce significantly until 25% of the authorized dose rate, that of less efficient fungicides until 50% of the authorized dose rate.

Therefore, dose rates can be reduced by 50-75% under practical conditions, but it is not possible in case of great regional risk and high infection pressure due to weather conditions.

Effect of fungicides depending on site, cultivar and dose rate



Treatment at GS65 (21.06.94) 1,0 l/ha=authorized dose rate
Assessment at GS79 (09.07.94)

Treatment at GS51/59 (20.06.94)
Assessment at GS72/75 (05.07.94)

In general, the following situations can be described to reduce authorized dose rates of foliar-acting fungicides in winter wheat (Table 3):

Table 3: Reduction of authorized dose rates of foliar-acting fungicides in winter wheat

Situation	Intensity							
Regional risk	high			low				
Infection pressure	low			high				low
Susceptibility of cultivar	low	average		low	average			
Efficacy of fungicide		high	moderate		high	moderate		
Possible reduction of authorized dosage up to (%)	75		50	75		50	75[1]	

[1] As far as possible, use of additional effects when controlling other diseases

In case of frequent occurrence of several diseases at the same time it has to be taken into consideration that the reserve action also normally varies and has to be calculated according to the disease which is most difficult to control.

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Evaluation and Enhancement of the Beneficials' Potential in Arable Farming
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A special concern of integrated crop protection is to take into account the action of native natural enemies and use it for integrated management. This inclusion is especially achieved by preservation and purposeful enhancement of **beneficial organisms** based on a good knowledge about the biology, population dynamics and the effect of enemies of harmful organisms. Although there is an enormous quantity of research results on beneficial organisms, it still proves to be difficult to evaluate the **situation-related beneficial effect** in relation to the situation. This is a result of long-term and manifold research activities in Europe and Northern America into relevant interactions in winter wheat.

Wheat fields in Germany house about 1000 different arthropods which distribute as follows: 30 harmful species (3%), 350 beneficial species (35%), and about 620 indifferent species (62%). Central attention is given to cereal aphids with their antagonist potential. The **interaction wheat - cereal aphids - antagonists** has turned out a special **tritrophic model system of natural control in arable farming**. It is increasingly used as indicator of the ecological situation in agricultural regions of Germany. Unfortunately, it is not easy to generalize the wide knowledge of the population dynamics and the effect of beneficial organisms and to use it for the situation-related evaluation of the benefits of beneficial organisms. This fact leads under a certain ecological euphoria in the developed countries to an overevaluation of beneficial organisms. This is underlined by carabids the regulatory action of which as epigeic predatory arthropods is extremely overestimated.

For this reason the BBA tries to quantify the beneficial effects in arable farming with the help of three methodical approaches: surveys in wheat fields, cage and climate chamber trials and simulation models which take into account all existing knowledge. An important aim is to obtain so-called beneficial thresholds. By beneficial thresholds we understand a beneficial density which can keep a pest population under control. It presents a great density range because it depends on several factors, for instance temperature. The special significance of temperature could also be quantified with the help of climate chamber trails and our simulation model GTLAUS. In case of temperature below 20 °C coccinellids show hardly any predatory effect and cereal aphids are relatively favoured.

A permanent problem of applied entomology is the **determination of beneficial densities** in the field. Each method has its peculiarities and faults, especially indirect density determination which is very popular at present, as for instance ground traps to survey epigeic predatory arthropods. Consequently, the correct evaluation of an ecological situation in agro-ecosystems presents a methodical problem which requires international research aimed at standard methods. It is also very important for ecotoxicological field experiments.

The **enhancement of beneficial arthropods** as a part of integrated plant protection includes indirect and direct methods. **Indirect methods** are the **preservation of beneficial organisms** by reducing respective adverse side-effects of plant protection products. Under this aspect everything is positive that contributes to purposeful and economical application of chemical plant protection products: decision-making on the basis of thresholds, timing of control measures, partial application and the selection of plant protection products. The BBA is very engaged in the IOBC/WPRS working group "Pesticides and beneficial arthropods" under the supervision of S.A. HASSAN. In addition to standardized laboratory tests and semi-field examinations side-effects under field conditions gain increasing importance. Side-effects of plant protection products are also examined under the registration procedure in Germany. Out of 958 products registered at present 46% have been examined. 60% of them are considered to be harmless. Unfortunately, there are not enough insecticides sparing beneficial organisms. Furthermore, they are relatively expensive in comparison to pyrethroids.

Another possibility to protect beneficials against side-effects is the reduction of the pesticide dose. Although farmers take a risk by dosing below the registration limit, they readily do so - more to save money than to spare beneficial organisms.

Direct enhancement of beneficial organisms includes the transmission of certain beneficial organisms, the improvement of the living conditions of various groups of beneficial organisms and the manipulation of their habitats. For the last years Germany research has been concentrating on field margin management and unsprayed field margins. **Field margin management** is the laying out of and attending to appropriate hedges combined with herb strips as boundaries to fields. **Unsprayed field margins** are in contrast pesticide-free margins of several meters within a cultivated crop. Past and present investigations carried out among others at several BBA-institutes revealed the positive effect of field margin structure elements on nature and species preservation. Greater floristic diversity in the agricultural region improves fauna diversity. Furthermore, a lot of beneficial organisms were found in field margins and pesticide-free field margins, for instance epigeic predatory arthropods, classical aphid predators and parasitoids. This beneficial potential has no doubt an influence on the margin of adjacent crops. However, we have not been able to prove so far that field margin structures promoting beneficial organisms supported natural control to such a degree that outbreaks of cereal aphids and other harmful organisms does not take place any more. Thus, manipulation of natural control provides only limited possibilities for integrated pest management.

It is particularly favourable to supplement natural control by purposeful biological control, for instance the application of beneficial arthropods from mass rearing. Expenses seem to exclude this possibility for arable farming. But there is an exception in Germany: the biological control of the European corn borer (*Ostrinia nubilalis*) by *Trichogramma* egg parasites. This method has been developed and implemented in practice with growing success by HASSAN and staff members. At present about 6000 ha are treated. The practical application of this method is officially supported by up to 100 DM/ha.

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Alternative Methods of Integrated Plant Protection

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The Current Situation

Over the past years, many efforts to find alternative control methods have been made. The literature holds the key to many solutions. The biggest problem is to transfer methods from the lab into practice. Furthermore, alternative methods generally do not have the same high reliability and/or efficacy as chemical plant protection products. Moreover, alternative methods require more sophisticated knowledge and they have to be fitted into the overall integrated plant protection concept. However, the reasons why farmers still rely heavily on the more convenient chemical plant protection products for pest control are mainly economic.

Alternative solutions cannot totally replace chemical crop protection products, but they must become a greater factor in the concept of integrated plant protection. Some non-chemical methods of pest control, for example biological control measures, are already well-known. The BBA was higly engaged in the development of the following biological products:

Product	Benefical	Target Pest
NOVODOR	*B. t. tenebrionis*	Colorado potato beetle
GRANUPOM	Granulosevirus	Codling moth
BIO 1020	*Metarhizium anisopliae*	Vine weevil
MILSANA	*Reynoutria sachalinensis*	Powdery mildew
Trichogramma	*T. evanescens* *T. dendrolimi* *T. cacoeciae*	Corn borer Apple leaf roller Plum moth
Lacewing flies	*Crysoperla carnea*	Aphids & thrips
Predatory mites	*Phytoseiulus persimilis*	Spider mites
Parasitic wasps	*Encarsia formosa*	White flies

In arable farming, only very few methods are available, e. g., mechanical weed control. Finding suitable non-chemical and alternative methods is a permanent challenge for researchers. Following are two examples from the BBA activities.

Induced resistance and induced tolerance

A number of research groups are working on induced resistance. The first resistance inductors are available to horticulture, and more are to be expected there and in other areas. The introduction of resistance inductors puts crop protection in a new situation. It is no longer the control of an acute situation of damage which is the basic strategy but the foresighted damping of an infestation curve. For some time going, the use of resistance inductors will have to be combined with direct control of plant diseases. Methodic helps must still be worked out, because the usual criteria for the use of plant protection products such as threshold values, first attack etc. are not appropriate to resistance inductors. Apart from searching for suitable resistance inductors, BBA institutes are trying to find out the mechanisms of action of these new means and fit them into the methods of practical crop protection.

A new starting point which has developed from this discipline of research is induced tolerance. Tolerance is a plant's ability to survive pest attack with less loss in productive capacity than a sensitive plant under the same intensity of attack. This distinguishes tolerance from the much studied resistance. Resistance and tolerance are host plant qualities which must be viewed separately and obviously have separate genetic roots, but which may be present in plants both at the same time. The degree of tolerance is measured by the productivity of the infested plants. The degree of resistance, on the other hand, is measured by the degree of infestation, the pest density or a similar criterion. Tolerance thus means less damage than in a non-tolerant plant in spite of the same degree of disease.

The course of a tolerance reaction in a host-parasite system is similar to the general adaptation syndrome. The stressor puts the organism in alarm, which first means a reduction in vitality. This is followed by a short pause of restitution and then a phase of resistance. The resistance phase is characterized both by defence reactions and by tolerance reactions, which include an increase in the plant's productive capacity with the aim to adapt to the stressor. Only if this adaptation does not take place, the plant enters a phase of exhaustion with irreversible damage.

Research at the BBA concentrates on the reactions taking place in the second phase, the phase of resistance, and their causal relations. The research has demonstrated that compensation reactions occur in many host-parasite relations and may also be induced by applying various substances. These compensation reactions in infested plants led to temporary increases in the productivity exceeding the productivity of non-infested plants.

It was also observed that the plant's productive capacity was stimulated over a period lasting until ripeness. This resulted in significantly higher yields. Such obvious stimulation, however, is rather the exception than the rule. Our further research wants to find out the reasons for that and find out more about tolerance reactions as a whole, with the aim to help in the breeding of low-input varieties, the improvement of prognoses of damage, and the search for tolerance inductors.

Non-chemical control

Biological methods to defend against damage have been reported in detail at the Darmstadt institute. We would like to add an overview of the physical methods which are worked on at the BBA institutes.

The research into physical methods centres on storage protection, horticulture and mechanical weed control in field cropping. Thermal methods have long been used in soil disinfection and in the treatment of seed, namely in wheat growing and forestry.

More recent methods have let the control of soil-borne pathogens by solarization seems to be practicable, but its use will be limited to certain regions. A new technique of physical seed treatment has been developed in the last decade - the use of electron beams to control seed-borne pathogens. The effectiveness of this new method against some seed-borne diseases is shown in the table. The biological action of electrons is based on physiological cell changes evoked by the energy of the accelerated electrons. The principle of electron seed treatment is to focus the action of the electrons to the surface layers and the near-surface layers of the seed, where the pathogens chiefly occur, without demaging the embryo situated underneath. Restricted action of electron beams to the outer layers of the caryopsis is feasible, because precisely selected technical parameters can be used. The most important parameters determining both the penetration depth and the effectiveness are the irradiation dose (kGy) and the acceleration voltage (kV). Intensive research work is necessary to optimize these parameters for the treatment of different seeds to sufficient fungicidal action without phytotoxicity. The development of the method for wheat is nearly finished, and now it only has to be introduced into practice. The application of this method is being investigated in other crops, like corn, rice, vegetable, forest seed.

Electron treatment is a completely new method of controlling seed-borne pathogens without chemicals. Further benefits are: residual seeds are not contaminated and there are no waste problems. Because the action of the electron is unspeficic, the development of resistance is not to be expected. The preconditions for combining this method with microbial systems are very promising. Following electron treatment, the seed surface is "clean" and therefore appropriate for applying antagonists to control the remaining seed-borne pathogens in the deeper layers of the seed as well as soil-borne pathogens.

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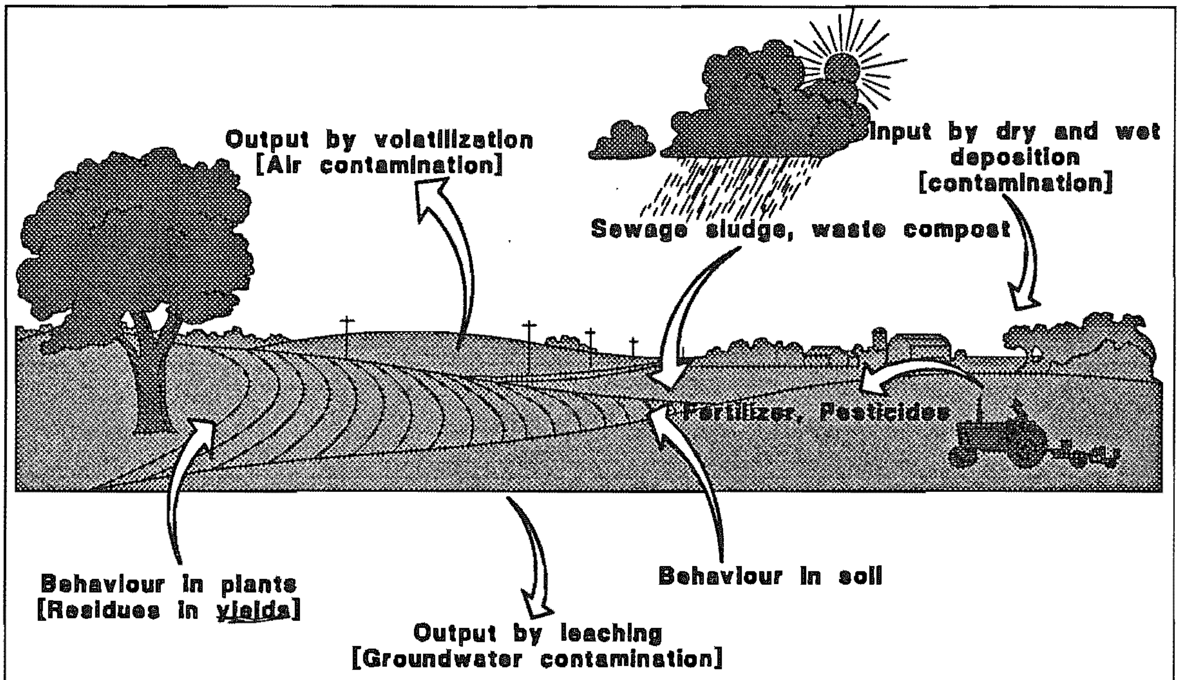
Distribution and Fate of Plant Protection Products in Soil, Water and Air

WILFRIED PESTEMER

Research on the behaviour of plant protection products and ecological relevant substances in the Institute for Ecological Chemistry of the BBA deals with:

- recording and evaluation of the long-term behaviour of chemicals, such as pesticides and their metabolites, nutrients, and noxious elements (e.g., cadmium, lead, or mercury),
- persistence within the environment, especially within agro-ecosystems and,
- research on non-parasitic plant disorders that serves as a basis for the identification of symptoms of damage in plants and for the development of treatment measures.



Investigation on persistence of ecological relevant substances in the enviroment

Following are three examples from the BBA activities.

Trace Analysis of Xenobiotics

The qualitative and quantitative assessment of xenobiotic pollution in the different compartments (soil, plant, air) is the basis for taking specific remedial measures. Virtually all crop protection treatment measures have side effects that accompany the desired protection of plants. It is up to research to assess and evaluate the benefit-risk-ratio.

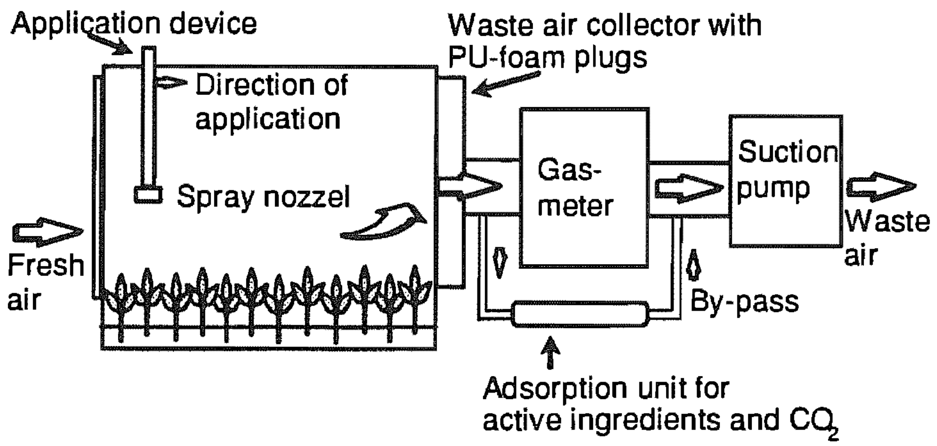
Furthermore, diffuse contaminations of crop plants are examined. These contaminations may come from a variety of sources (e. g., industry and motor vehicle emissions, households, agriculture).

A prerequisite for obtaining reliable data is the use of modern analytical technology, e.g., gas chromatography with specific detectors and in combination with mass spectrometry, high performance liquid chromatography, atomic absorption and emission spectrometry, voltammetry etc..

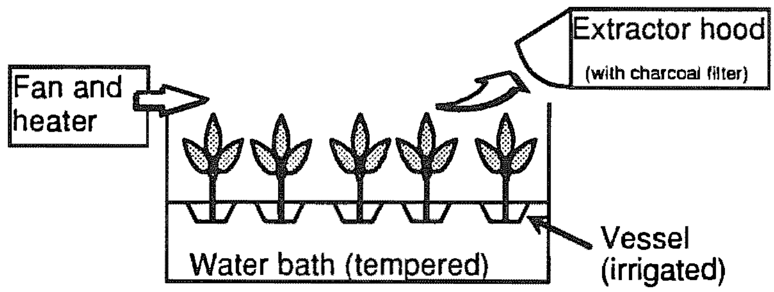
Volatilization of Plant Protection Products

If pesticides volatilize during or after application, they may be widely distributed through and with the atmosphere. For the conduct of model experiments, there are two experimental facilities in which volatilization of pesticides from plant and soil surfaces can be measured (see figures above).

Both facilities allow pesticides to be applied to plant or soil surfaces in a manner very similar to that used in agricultural practice. Air is sucked through the closed experimental chamber (Volume ca. 1 m^3), that contains plants or soil, and carries the volatilized components of the applied pesticides with it. These components are then adsorbed to a suitable filter and directly and quantitatively analysed.



Closed volatization chamber



Open volatilization chamber

In the technologically less sophisticated open chamber, air is blown over leaf or soil surfaces and the pesticide residues on these surfaces are then assessed indirectly.

In both cases, the conditions (wind speed, soil and air temperature, humidity and soil moisture) under which the experiments are conducted, can be controlled and varied according to field conditions.

With both facilities, radioactive pesticides can be used, which makes quantitative analysis of volatilization rates much easier. The data obtained from these experiments are intended to serve as a basis for a computer supported expert system that estimates the dangers imposed on the environment by pesticides.

Development of an Expert System (PEMOSYS = Pesticide Monitoring System) for Recording of Long-Term Behaviour of Pesticides

According to a recommendation of the FAO and a guideline of the EEC, post-registration activities to investigate long-term effects of pesticides should be carried out in all member countries. This includes both the assessment of the behaviour (chemical monitoring) and of side effects (biological monitoring).

Even when pesticides are applied properly and only for the intended purpose, a certain risk of environmental contamination remains. Therefore, in some justified cases post registration studies regarding the behaviour and persistence of pesticides are required according to a recommendation of the FAO and a guideline of the EEC. In order to meet this demand as efficiently as possible, the expert system PEMOSYS has been developed. This system facilitates the simulation of the behaviour (degradation and leaching) of pesticides. PEMOSYS was developed to facilitate a large-scale monitoring using a wide range of soils and climatic conditions (scenarios). The prototype includes three main parts (ANPROG, CHEMPROG and VARLEACH), which can use the same data base. ANPROG: long-term prediction of pesticide residues in the upper 10-cm-layer of soil after repeated applications; CHEMPROG: the assessment of groundwater contamination hazards using rule-based systems; VARLEACH: for prediction of the distribution of pesticides in the soil profile using the implemented simulation model. As a framework, a 'Geographical Information System' (GIS) has been chosen, which enables a clear presentation of stored data (soil classifications according to the German guideline and measured soil properties) and simulated results imbedded in maps of the respective region. As reference areas, mainly the well investigated experimental sites of the Federal Biological Research Centre with a wide range of soil and climatic conditions will be included. Using PEMOSYS, possibly critical situations in certain ecosystems or regarding soil or climate conditions can be detected quickly, and if neccessary, further studies at the critical sites can be carried out.

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Research on Ecotoxicological Effects of Plant Protection Products

HANS BECKER

In 1986 the protection of the natural balance was explicitly included in the Plant Protection Act in Germany. The tests required for evaluating the impact on the natural balance are single species tests carried out if available on the basis of OECD guidelines for the testing of chemicals and if not, on the basis of national guidelines. According to the uniform principles for evaluation and authorization of plant protection products (EEC Council Directive 94/43/EC), the authorities evaluate whether under the proposed conditions of use an exposure of organisms is possible. If this possibility exists they determine the degree of short-term and long-term risk to be expected after use of the plant protection product according to the proposed conditions of use. The EC stipulates also principles for decision making regarding the authorization.

The impact on the natural balance or the environment may of course only be evaluated on the basis of the results obtained from the single species tests. In this connection the uniform principles point out the following. Since the evaluation is based on data concerning a limited number of representative species, member states shall ensure that the use of plant protection products does not have any long-term repercussions for the abundance and diversity of non-target species.

The investigation of the effects on organisms and communities in agro-ecosystems and adjacent freshwater systems caused by authorized plant protection products (monitoring after authorization) is the fundamental duty of the Institute for **Ecotoxicology in Plant Protection** in Kleinmachnow and Berlin.

Besides the ecotoxicological investigation of plant protection products after authorization or of plant protection measures the institute takes an active part in the development of ecotoxicological test methods for the OECD and ISO/TC 190 (Soil quality) and is involved in the evaluation of substances according to the German Chemicals Act or the EEC Council Directive 92/32/EEC relating to dangerous substances (not plant protection products).

The ecotoxicological studies comprise the following organism groups:

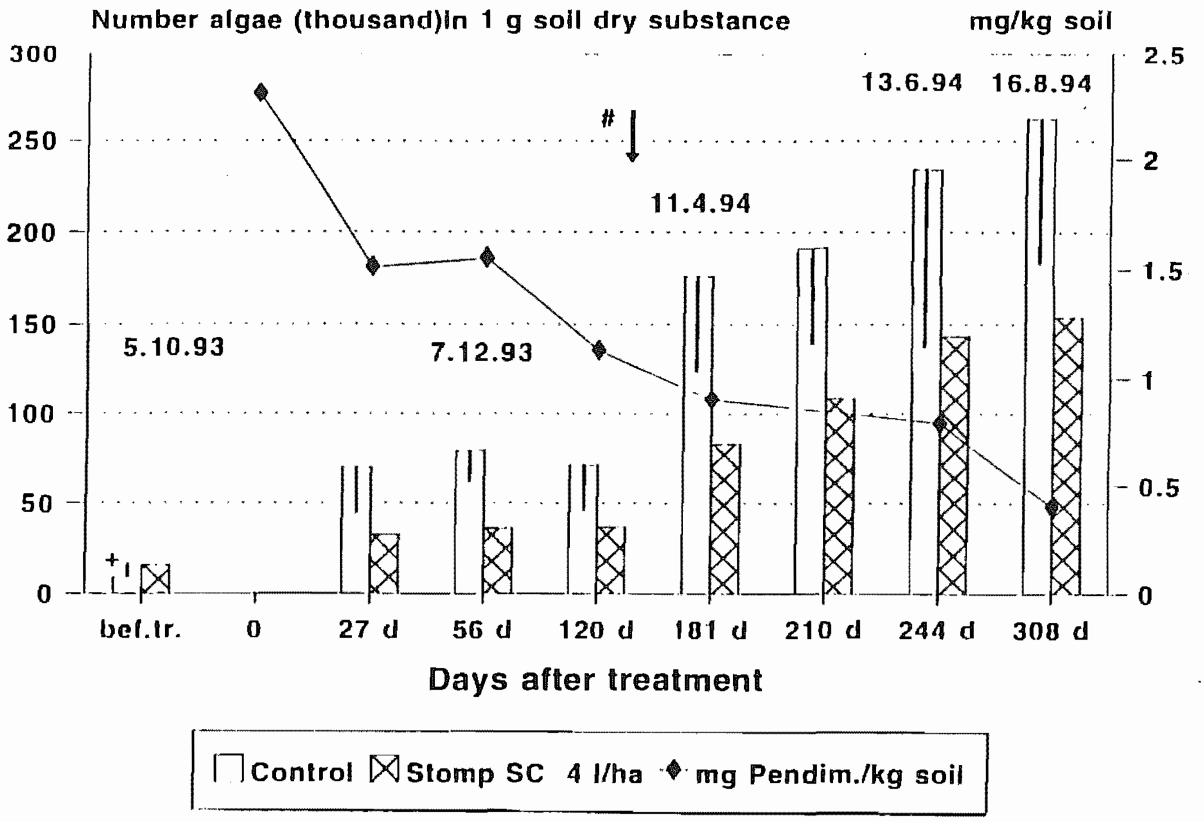
- Soil algae
- Soil microorganisms
- Soil fauna, especially springtails (Collembola, Insecta) and predatory mites (Gamasina, Acarina)
- Predatory mites (Gamasina) and spiders (Araneida)
- Freshwater phyto- and zooplancton
- Periphyton and zoobenthon in freshwater.

Field tests for determining the effects of plant protection products on organisms are combined with intensive chemical analysis in order to evaluate the released quantity of a substance, its degradation and availability for the organisms. If possible, findings from field tests should be confirmed by laboratory trials.

For illustration some research projects shall be described:

Determination of effects of the herbicide STOMP SC on soil algae.
The herbicide, containing the active ingredient Pendimethalin, has been applied on the basis of the normal application rate (1600 g a.i./ha). For determining the algae and the residues soil samples were taken from a depth up to 5 cm. 10 to 20 mg soil are distributed on a special agar and incubated during a period of four weeks. The influence of the herbicide is determined as number of algae colonies per Petri dish. The diagram shows the sum of all species (fig. 1).

Figure 1: Influence of STOMP SC on soil algae in winter barley 1993/94



Date of treatment:12.10.1993 Güterfelde + GD alpha 0,05 # 80 kg N/ha

Up to 308 days after application all samples taken from the treated plot showed a significant difference of algae density in comparison with the control. The reason for this long period of action is supposed to be due to the slow degradation of Pendimemethalin (DT 50, 140 d) and the low water solubility (0,3 mg/l). The substance was classified as highly toxic for aquatic algae. The same applies apparently for soil algae. The quantity of 0,4 mg/kg soil of Pendimethalin determined at the end of the trials seems still to be within the range of measurable inhibition effects.

Impact of FENIKAN on the soil fauna with tillaged and non-tillaged soil cultivation

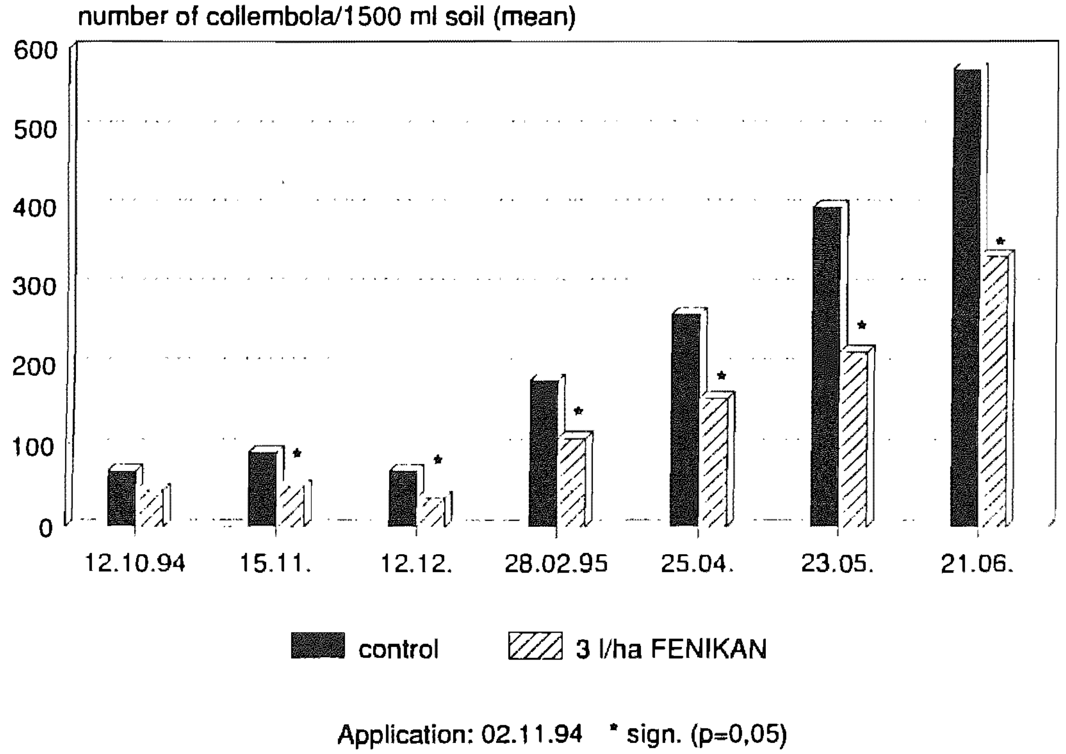
The Institute of Integrated Plant Protection carries out a long-term project in Glaubitz (Saxony) with the objective of determining the effects of herbicide application, mechanical herbicide control and crop rotation on weeds. This long-term project is also used for eco-toxicological investigations on the soil fauna.

Between October 1994 and June 1995 the investigations relating to the soil mesofauna were carried out on the plot treated in November 1994 with FENIKAN (a.i. 187,5 g Diflufenican + 1500 Isoproturon/ha) and the untreated control with tillaged and non-tillaged soil management. From the four test plots (n=4) the collembola and soil mites were extracted from a soil quantity of 1,5 l each.

The maximum of a test plot of extracted collembola amounted to 47,000 individuals/m^2 . The results obtained from 7 samples taken at different times showed that the abundance on the un-ploughed and untreated plots was almost three times as high as that of the treated, ploughed plots.

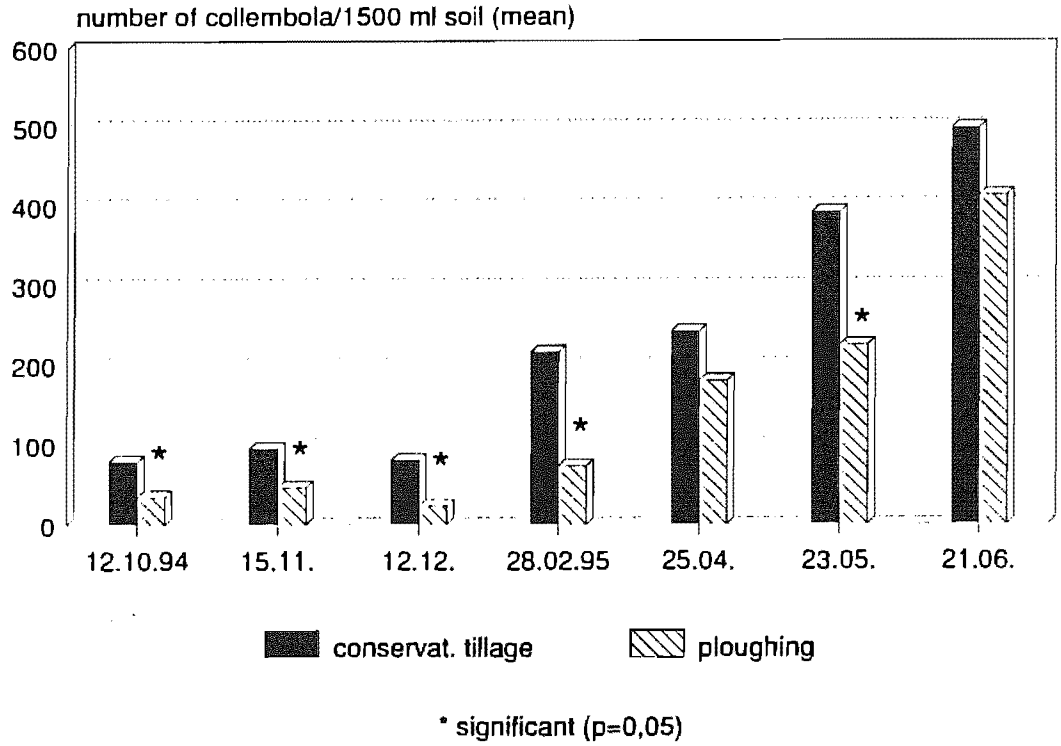
The statistical evaluation of the trial (fig.2) showed from November 1994 on due to the her-bicide treatment a significant diminuation of the collembola abundance with an average of 42 %. This may be due to slighter direct effects as well as to strong indirect effects caused by the change of vegetation. The difference already at the starting point may have been caused by the accumulation of the effects during several years of the long-term study.

Figure 2: Effects of herbicide application on collembola in winter barley



A similar negative effect with an average reduction of 38 % was observed also, if the soil was only ploughed (fig.3). The effects on predatory mites and other soil mites showed the same tendency but were not so clearly developed.

Figure 3: Effects of cultivation on collembola in winter barley



Run-off of plant protection products in small running waters

The Plant Protection Station in Hannover and the Institute for Plant Protection of Field Crops of the BBA support a project which is concerned with practice oriented procedures in order to avoid the immission of plant protection products in surface waters by wind drift and run-off.

On two agricutural crop areas situated in the catchment area of a small running water an investigation shall be carried out comparing the non-tillaged area with the area cultivated in a conservative manner in order to find out whether non-tillage soil cultivation leads really to a reduction of run-off of plant protection products. As in the catchmend area of the waters several crops are cultivated and the farmer decide themselves whether plant protection products shall be applied. About 35 active ingredients have to be considered for residue analysis by the Institute for Ecological Chemistry. The Institute for Ecotoxicology in Plant Protection investigates the zoobenthos, i.e. the animals living on the bottom of the water such as worms, snails and crabs, insects and periphytical algae, in four sections of the two water bodies.

For the monitoring of the algae growth specimen holders and plastic sheets are placed in the water bodies on which the algae colonize. Thus 32 algae species were determined, seven of them occuring in all four water sections. We are not sure whether these studies will allow conclusions on certain plant protection products or run-off events. But they give us an insight in the biodiversity of the water bodies in the agricultural landscape.

The objective of the ecotoxicological research of the institute is, besides the information about possible dangers for plants, animals and their life communities, to provide a scientific support in order to guarantee a sustainable agriculture in a landscape with a great diversity and intact element cycles.

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Institute for Plant Protection in Fruit Crops - Subjects of Research

ERICH DICKLER

Integrated Fruit Production

Integrated fruit production (IFP) is the logical development of integrated pest management, a technique aimed at being harmless to the eco-system and which has reached its greatest maturity in apple production. In many European fruit growing areas IFP has been implemented widely in commercial pome fruit production under the convenorship of the Dossenheim institute and as a result of an exemplary collaboration between more than 50 experts from 14 European countries the general principles, guidelines and standards for integrated production of pome fruits in Europe were set out in a bulletin. It was published by a joint group of the International Organisation for Biological and Integrated Control (IOBC/WPRS) and the International Society for Horticultural Science (ISHS) and is now available in a second edition.

Fungal Diseases

The most important fungal disease is apple scab caused by *Venturia inaequalis*, which has to be controlled either by the regular application of protective fungicides or by curative fungicides based on the predictions of infections. The other fungal diseases are mostly of minor importance and are eleminated with sprayings against scab. Apart from weather conditions, the most important factors for the infections are the primary fungal inocula as ascospores or overwintering conidia and mycelia and the susceptibility of plants altered by the maturity of tissues and by the apple cultivar. With gaining all the important biological data we could improve the knowledge of infection parameter and we will significantly improve the efficiency in scheduling fungicide applications. Monitoring ascospore flight in the orchard and the use of an bioassay with apple seedlings exposed in the orchard are most relevant for detection of real infections in the orchard. Because of the high amount of work and instrumentation for determination of a highly sensitive and exact quantification of ascospores we develop alternative methods for quantification which could be evaluated easier for the development of better management strategies. The plant features included in the investigations are ontogenetic resistance, cultivar resistance and differential cultivar susceptibility. Loss of cultivar resistance and ontogenetic resistance could be described and investigations on fungal races and the causal environemental factors in the orchard will be continued.

Virus Diseases

Plum pox virus (PPV) is the causal agent of skarka disease in plum. PPV is a quarantine pathogen and the most important virus in German fruit production. In the institute the epidemiology of the disease is investigated in field, greenhouse and laboratory experiments. The development of strategies to control the disease within integrated production programs and diagnosis are primary research topics. This includes studies to investigate aphid transmission efficiency of various virus isolates. Different woody and herbaceous hosts are examined for virus infection, sensitivity and symptom expression. As eradication programs failed in the past to manage the problem, emphasis is put on the investigation of plum varieties and rootstocks for virus tolerance and resistance. This work also includes characterization of a wide range of different isolates using polymerase chain reaction (PCR), nucleic sequencing and analysis of gene functions.

Within integrated production programs the effects of latent viruses in pome fruits are being investigated. Field trials demonstrated that virusfree apple varieties were more vigourous and superior for replanting when compared with virus-infected material. The experiments include evaluating effects of virus diseases in highly sensitive and very young trees. Virus characterization and development of different laboratory and greenhouse detection techniques are supporting the elimination of latent viruses for plant propagating material.

Development of resistant rootstocks for apple and pear to control phytoplasma diseases
In Germany, the phytoplasma diseases of apple (apple proliferation, AP) and pear (pear decline, PD) are of considerable economic importance. Both diseases have increased in importance during the last years, which might be favored by integrated pest managment programs in which the number of applications of insecticides being active against the insect vectors is reduced. As an alternative to vector control, other possibilities to prevent damage by AP and PD were examined. As it was discovered in previous work that the causal agents of the two diseases are unable to overwinter in the aerial parts of the trees, it was attempted to control AP and PD by the use of resistant rootstocks. However, inoculation experiments showed that all established apple rootstocks, which all descend from the cultivated apple (*Malus domestica*), and the pear rootstocks derived from French pear (*Pyrus communis*) are suitable hosts of the AP and PD phytoplasmas, respectively. These rootstocks remain permanently infected, and the trees grown on them are moderately to severely affected by the respective disease. Screening of many wild and ornamental *Malus* and *Pyrus* genotypes revealed that most of them are more susceptible than the established apple and *P. communis* rootstocks. In contrast, several experimental apple rootstocks were found, which all derived from crosses between *M. domestica* and *M. sargentii* or *M. sieboldii,* that showed suitable resistance properties. Upon infection, trees on such rootstocks are slightly affected over 1 or 2 years. Then they recover and perform like noninoculated trees. Furthermore, such rootstocks are unsuitable hosts in which the infecting phytoplasma populations decline within 2 or 3 years. Re-appearence of disease has never been observed on trees grown on such rootstocks. Plants showing similar resistance properties were detected among seedlings of various *Pyrus* taxa. Such genotypes are now being propagated and will be examined for rootstock properties. Suitable resistance to the PD phytoplasma has also been observed in some quince (*Cydonia oblonga*) rootstocks for pears.

Insects and Mites
Research activities with regard to environmentally and ecologically safe control of insect pests and mites covers different strategies:

- Release, enhancement and preservation of beneficials
- Development of biotechnical control techniques
- Investigations on side-effects of pesticides on beneficial organisms
- Reduction of the number of pesticide treatments with the help of prediction models and the use of threshold levels

The introduction of predatory mites, mainly *Typhlodromus pyri* SCHEUTEN (Acari, Phytoseiidae), to control spider mites is well established. As sometimes, however, biological control fails, research in this field continues. Investigations on releasing *Trichogramma* spp. (Hymenoptera, Trichogrammatidae) for biological control of tortricids have given promising results. Possibilities how to improve the efficiency of *Trichogramma* have been worked out and will be realized in future. - A prerequisite for the enhancement of beneficials is a balanced and natural orchard environment with a diverse ecosystem of plants. A project has been started in 1994, where flowering herbs and herbaceous perennials are introduced into the orchard to attract beneficial arthropods, especially aphid antagonists. Beneficials can be preserved by using selective pesticides based on microorganisms (*Cydia pomonella*-granulosis virus, *Adoxophyes orana*-granulosis virus, *Bacillus thuringiensis kurstaki*), biotechnical control techniques (mating disruption or confusion technique, attract and kill technique, color traps) as well as with synthetic pesticides which do not or only slightly harm non-target organisms. Research on side-effects of pesticides on non-target organisms, therefore, is one of the main subjects and covers laboratory, semi-field and field investigations. Quite recently two field methods have been developed at the institute: one for the green lace wing, *Chrysoperla carnea*, one for the egg parasitoid, *Trichogramma*.

Another main research subject is the development of prediction models in order to optimize the timing of pesticide treatments as well as to reduce the number of applications. So far a prediction model for *Cydia pomonella* (Euro-Bugoff) has been established and one for *Adoxophyes orana* is worked on.

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Institute of Biological Control - Subjects of Research

JÜRG HUBER

The institute deals with the fundamental and the practical aspects of biological pest control in agriculture and forestry. It is the only institute in the Federal Republic of Germany spezialized in this particular field of plant protection. Biological control is an important element in modern integrated plant protection systems.

The main tasks of the institute are:

- Studies on the role of predators, parasites and other antagonists as natural enemies of pests; the development of methods for their mass production and utilisation as well as measures to project them from side effects of non-selective pesticides.

- Research on viruses, bacteria, fungi and other pathogens of pests, their diagnosis, pathology, propagation, and practical utilisation.

- Research on insect allelochemicals, natural defense substances of plants, and other biotechnical methods.

Entomophagous Nematodes/Ecology

The use of entomophagous nematodes in biological control and the effect of these nematodes on non-target organisms. Evaluation of biology, ecology and occurance of pest insects. The significance of natural biotops within the agricultural ecosystem (e. g. boundary strips, unsprayed crop edges, and fallow land) to beneficials and pest and the effect to their cultures.

Phytopathology

Biological control of plant diseases. Development of methods for the control of soil- and seed-borne plant diseases with microbial antagonists.

Phytobacteriology

Biocontrol of bacterial diseases on the basis of resistance induction by plant extracts and antagonisms. Evaluation of the mode of action.

Botanical

Use of plant extracts as plant strengtheners to induce resistance against phytopathogenic fungi and bacteria. Evaluation of plant extracts to be used as pesticides, bactericides and fungicides.

Beneficial Arthropods

Mass production and utilization of entomophagous arthropods (parasites and predators) to control insect and mite pests. Testing the side effects of pesticides on beneficial arthropods; Quarantine for imported entomophagous arthropods.

Diagnosis and Histopathology

Diagnosis of insect diseases; histo- and cytopathological studies using ligth- and electron microscopy; research and use of protozoan diseases in biological control; prognosis to limit pest calamities using insect pathogens. Rearing of insect cultures.

Virology

Virus diseases of insects; basic research and application in plant protection. Research related to registration of viral insecticides. Risk-assessment with genetically engineered baculoviruses.

Bacteriology

Bacterial diseases of insects; fundamental and applied research on Bacillus thuringiensis. Research on the safety of production and use of insect pathogens in connection with the registration of biocontrol products.

Mycology

Fungal diseases of insects. Ecology, production and use of entomopathogenic fungi. Testing of commercial fungal preparations for the control of insect pests and plant diseases. Research related to the registration of fungal preparations. Biocontrol of slugs.

Locust Control

Research on microbial control of locusts and grasshoppers.

Application techniques and control methods

Development of methods for application of microbial insecticides. Integration of non-chemical methods in plant protection systems.

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