Potential and limits of biological control with beneficials in greenhouse ornamentals

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INTRODUCTION

Biological control with beneficials (biocontrol) is a long known successful story in vegetable production. In the last decade biocontrol in ornamentals became an interesting field of use in various ornamental crops such as poinsettia (Euphorbia pulcherrima) and bedding plants. Owing to the specific demands of ornamentals, biocontrol is also a field of research in manyt countries and is, therefore, discussed in international working groups (e.g. the International Organisation of Biological and Integrated Control, IOBC). The increasing importance of biocontrol in practice is due to different aspects: to a sophisticated view towards the side-effects of pesticides on the environment and to problems with pests resistant to insecticides; thirdly, to a lack of registered and recommended pesticides; and lastly, but not least, to developing concerns of growers towards their own health and safety.

ADVANTAGES AND DISADVANTAGES OF BIOCONTROL IN ORNAMENTALS

Biocontrol has several advantages over chemical control (e.g. beneficial organisms generally have no negative impact on the environment). This is true for native species, although not necessarily so for alien species. Certainly, beneficials do not leave chemical residues in food and there is no pre-harvest interval; nor do they hold any risks for the user. Instead, their implementation in cropping systems often offers a longer period of efficiency and a very low risk of resistance to the controlling agent. Nevertheless, there are some difficulties in handling beneficials particularly, where many different crops (which might be infested with different pests) are produced in varying production systems. In the beginning beneficials act slowly, the action threshold is pretty low and problems rise if additional pests or diseases occur. Consequently, biocontrol requires high advisory input and growers need up to 3 years patience until the biological system is established. Above all, biocontrol is slightly more expensive.

SPECIAL DEMANDS ON USING BIOCONROL IN ORNAMENTALS

Ornamental species and cultivars vary considerably – there are foliage and flowering plants, herbaceous and woody plants, and native as well as exotic species. Exotic species are often imported from other countries, which means from other climates and areas with a different, unknown and diverse spectra of pests and diseases. The wide range of pests and diseases with their corresponding beneficials makes biocontrol a complex system. Even the production systems vary immensely – for example, potted plants vs cut flowers; production in soil vs production in artificial media. In general, quality standards for ornamentals are extremely high. The produce must be completely free of insects, mites or any damage. For potted plants this means the whole plant must be free compared with greenhouse vegetables (such as cucumbers or tomatoes) where only the fruits are considered.

INTEGRATED PLANT PROTECTION MANAGEMENT

To cope with the high demands for quality of ornamental plants, there is often a need to integrate pesticides with biocontrol. For example, during the summer, adult thrips invade greenhouses and cause damage to flowers, often over a period of several weeks; they then leave the greenhouses. Generally, predatory mites can succesfully cope with a thrips outbreak in the crop, by feeding on the nymphs. However, the invading insects are adults. In springtime, some beneficials are insufficiently active, as it is either too cold or there is not enough light. This is the case for whiteflies and their parasitoid *Encarsia formosa*. If a grower wishes to adopt a biocontrol strategy, he should use selective pesticides for at least six months before commencing. This is necessary to decontaminate the crop. A heavy outbreak of a pest shortly before marketing can make a pesticide treatment necessary. Also, for some pest species no adequate beneficial organisms are available. Diseases are usually controlled by fungicides.
Thus, there is an urgent need to know about the side-effects of pesticides (i.e. whether they are harmful to beneficials and how persistent is their detrimental effect). This will help growers to select and time appropriate pesticide treatments. If a pesticide has a long-lasting detrimental effect on beneficials its use can lead to serious problems.

BIOLOGICAL/INTEGRATED CONTROL OF WHITEFLIES IN POINSETTIA

Controlling whiteflies (*Trialeurodes vaporariorum*) with *Encarsia formosa* in poinsettia has been a successful example for biocontrol programmes for many years. However, in recent years this strategy has been questioned because of its reduced efficacy. That is why the influence of different insecticides, particularly imidacloprid (Confidor WG 70), on searching and parasitation behaviour of the parasitoid was examined. In addition, tobacco whitefly (*Bemisia tabaci*) is on the increase in German horticulture, a species that chemical insecticides as well as beneficial organisms fail to control; one reason for the reduced efficacy of chemical protection is the fast development of resistance. Biocontrol could prove to be an alternative. Hence, the parasitic capacity of *E. formosa* was examined. The results showed that many insecticides have a repellent impact on *E. formosa,* so the wasps do not approach treated plants. In particular, imidacloprid (frequently used in stock plants) has a long-lasting repellent and lethal effect, lasting for 16 wk after spraying and for even longer after drenching. To control tobacco whitefly with *E. formosa* a minimum release of one wasp per plant is necessary and the mode and quantity of parasitoids released have to be adapted.

ECOMONIC EVALUATION OF BIOCONTROL

Implementing a biological control system requires a phase of reorganisation and adaption, with a high input of beneficials and monitoring. A recent economic evaluation of long-term benefits included consideration of the direct costs (over 6 years) for plant protection measures from two nurseries producing cut-flower roses. When the project began, costs in both nurseries were much higher than for conventional pest management (at, overall, 2.79 €/m2 and 2.89 €/m2). During the project, however, costs could be reduced significantly to 1.20 €/m2 and 1.27 €/m2, respectively, which is comparable to conventional production. Biological control systems have other important benefits that cannot be evaluated directly, such as growers' concerns towards their own health and safety, better plant quality, and the availability of alternatives if there is a lack of efficient pesticides or if pests become resistant. Hence, biological control has essential advantages in the long-term, as well as social and environmental benefits.

www.isip.de – online plant protection information in Germany

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INTRODUCTION

ISIP, the Information System for Integrated Plant production, is a Germany-wide online decision support system. It was initiated in 2001 by the German federal extension services as a common advisory portal, thus achieving synergies by pooling existing information. Despite the centralised character of the system, the regional identity of the co-operating services was to be preserved by a dispersed administration and data input. With the start of the system, the ISIP association was established; by 2007, this comprised eleven of the sixteen federal extension services in Germany. The office of the association, currently with four employees, is in Bad Kreuznach, Rhineland-Palatinate. Since information transfer is the primary task of extension services, the system is intended to make this work more efficient by using modern information technology. Therefore, a bi-directional data flow between the services and farmers was developed. By combining general with specific data, recommendations can be refined from regional to individual.

INFORMATION CONCEPTS

Three types of information can be distinguished in ISIP, each differing in scale. Decision support modules (DSMs) deliver the most specific results. They comprise results from a simulation model and/or monitored field observations, as well as a comment from the regional extension worker. This 'threefold decision support' gives a comprehensive overview for a defined pest or disease. More general information is provided in regional news. The members of ISIP can maintain their own starter pages in the system, where they can distribute topics ranging from contact data to legislative news. Furthermore, paper-based warning and information services are made available for download as PDF documents. The most general information is given in the encyclopaedia, where background information and standard recommendation for more than 20 crops and 200 pest and diseases are stored in a database.

Subsequently, a closer look will be drawn to the DSMs as implemented in the system. The different elements of the modules are represented in a defined colour scheme: the comment of the regional extension worker is marked in red; simulation results are shaded in orange and monitoring data shaded in green. This scheme and a limited set of icons provide a consistent interface for the user: e.g. a calculator symbol links to a form, where the user can input his information. With sending these to the server, the data are stored and the model is run, returning an individual result. The model is re-run whenever the weather data are updated, thus giving a new result every day. To release the user from having to check the system daily, an automatic warning service can be set up. When a module-specific threshold is reached, an SMS or e-mail is generated by the system and sent to the user. As of 2007, eight DSM are available, while another seven modules are currently under development.

TECHNICAL CONCEPTS

The software architecture of the system can be distinguished in three main tiers: the presentation, the application and the database. The presentation tier consists mainly of HTML pages, to be viewed in a standard web browser. The application tier comprises the system kernel, with prognosis models and other modules, such as import and export routines or scheduling functions. Finally, in the database tier, all necessary information – primarily weather data – for the model calculations is stored.

To facilitate the integration of new models, a 'master component' was developed. This component comprises an application programming interface (API) to both the presentation and the database tier. A model frame connecting the two APIs is ready to receive new simulation algorithms; thus, this master component can be used as a template for model development. Apart from JAVA programming knowledge, the model developer is relieved of technical details of the system framework, and can focus on the quantification of the functional relationships. The final outcome is a fully functional ISIP component, which can easily be implemented into the system. Model development with the ISIP master component is a three-step process, the first of which is development of the scientific model. To support this, a bare-bone ISIP system is installed on a local computer, comprising the application and the database tiers only. After the model has been evaluated, the integration into a non-public internet environment follows. Here, a number of technical tests are run. If the new model passes these tests, the final step is the release to the public production server.

DISCUSSION

The advantages of the ISIP system differ between the two target groups. On the one hand, the farmer gains most from the on-line calculation of prognosis models which deliver site-specific recommendations. Furthermore, the consistent user interface eases the acquisition of information. The automatic warning service by SMS or e-mail reduces online and response times, especially for time-critical decisions. On the other hand, extension workers benefit from the web-based input of monitored field data and advisory comments. This eliminates further processing, and ensures a fast and efficient transfer of information.

In the near future, new DSMs for plant protection will be included. Additionally, a special focus will be set to agronomic and horticultural model approaches. The encyclopaedia will also be extended on an even more comprehensive scale. On the technical side, the data exchange with farm management information system (FMIS), via the exchange language agroXML, will be enforced. A milestone will also be the upgrade of ISIP with a geographical information system (GIS). The added value of ISIP are its up-to-date site-specific DSS modules, complemented with the latest regional news and a large database of background information. The software framework of ISIP is built in an open and extensible architecture, which helps to speed up model development and ensures rapid transfer of knowledge. Hitherto, the information flow was more or less unidirectional, from the extension services to the farmer. With ISIP, an interactive network for information exchange between model developers, data providers, extension services, farmers and others is established. Using the internet as the linking platform, ISIP is a comprehensive tool for decision support in integrated plant production.

Development of new forms of biopreparation on the basis of biocontrol *Trichoderma* strains by using wooden residuals

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INTRODUCTION

Some of the most widely used biocontrol agents in the world belong to the fungal genus *Trichoderma* (Samuels, 1996). In particular, isolates of *T. harzianum*, *T. virens* and *T. hamatum* are used against diseases in a wide variety of economically important crops. However, standart strains in agriculture practice are giving inconsistent control between different nurseries and seasons, and seemed to be ineffective for reforestation in unfavourable years. Screening effective isolates within the aboriginal strains of *Trichoderma* may open new perspectives for biological control soil-borne pathogens (Gromovykh *et al.*, 2003). Wooden organic compounds, as byproducts of paper industries, have great potential as native suppressives of damping-off in forest seedlings. Multiplying *Trichoderma* spp. on such substrates could be beneficial for field application in forest nurseries.

METHODS AND RESULTS

All isolates of *Trichoderma* and *Fusarium* were obtained from forest nurseries soils of Central Siberia. *Trichoderma* spp. were tested against *Fusarium* isolates, using dual culture and antibiotic disk techniques (Egorov, 1985). Five organic substrates (pine bark, larch bark, the same substrate after CO_2 and also hydrolysis lignin) were evaluated for their ability to support the growth of different *Trichoderma* spp. After sterilization, the substrates were inoculated in a fermenter under aseptic conditions, with 1×10^6 spore/g. Deep solid fermentation was done for 8 days with aeration. The population of *Trichoderma* on the organic substrates was assessed by a serial dilution technique, using *Trichoderma* medium. Populations of *Fusarium* and *Trichoderma* were monitored in forest nurseries in two fields in 2002–2004 by the serial dilution technique. Disease severity was recorded at the bunch maturing phase, using a 1–5 scale. Trials were laid out in a randomized block design, each being conducted at least twice.

Collections of 197 selected isolates of *Trichoderma* (*T. asperellum*, *T. viride*, *T. harzianum*, *T. koningii*, *T. virens*) were analyzed with respect to their antagonistic activity against the main representatives of *Fusarium*. Strains providing the best control in the artificial light laboratory were then evaluated in small field plot tests. The screening has led to the selection of 15 aboriginal strains as a potential biocontrol agents. Monitoring of the single-spore clones of these 15 wild isolates has demonstrated high heterogenity with respect to culture-morphological properties, sporulation and the antibiotic activity of *Fusarium* species. Regarding these indexes, all isolates can be split into four distinct groups, with which vegetative compatibility corresponds. These data were used as a basis for further selection within the given group for the development of biopreparations. For this purpose, solid biotechnology systems on different subsrates (including pine bark, larch bark, the same substrate after CO_2 and ethanol extraction and also hydrolysis lignin) were investigated. Larch bark after CO_2 extraction was the best substrate to support the growth of *Trichoderma*, which quickly multiplied and covered the entire surface within 6 days (Table 1).

Table 1. Number of *Trichoderma* propaguls on different wooden residuals.

Substrate	Yield of spore, (M ± m), $*10^8 * г^{-1}$			
	МГ/6	К-12	10 - 99/5	МО
Hydrolysis lignin	0.65 ± 0.04	0.13 ± 0.03	0.85 ± 0.01	0.19 ± 0.03
Spruce bark	2.34 ± 0.06	1.79 ± 0.01	2.29 ± 0.04	1.53 ± 0.06
Spruce bark after CO_2 extraction	3.57 ± 0.02	3.57 ± 0.02	2.40 ± 0.03	2.14 ± 0.03
Larch bark	1.90 ± 0.01	1.21 ± 0.03	1.81 ± 0.03	1.33 ± 0.03
Larch bark after CO_2 extraction	3.90 ± 0.01	3.20 ± 0.06	2.67 ± 0.03	2.38 ± 0.06

A different form of biopreparation was done for the evaluation in forest nurseries of *Picea obovata* seedlings: МГ 97/6 *Trichoderma asperellum* on pine and larch bark after CO_2 extraction (containing 3×10^8 spores/g). Complex biopreparation consisted of МГ– 97/6 *T. asperellum*, M 99/5 *T. harzianum*, K-12 *T. asperellum* and MO *T. hamatum* (containing 2.5 $\times 10^8$ spores/g) on pine bark. The results showed that treatment of spruce seeds and seedlings could increase the number of healthy seedlings: biopreparation on larch bark by 4 times; biopreparation on spruce bark after CO_2 extraction by 3.4 times. The maximum percentage of healthy seedlings (8.5 times greater than the control) was achieved with a complex of bioprepraration s.

DISCUSSION AND CONCLUSION

The success of biological control on crop plants depends not only on effective antagonists but also on the costs involved and the method of application. Complex biopreparation using larch bark were cost effective, had a long shelf-life, supported high propagules density, were easy to formulate and achieved effective disease control.

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Enhancement of biopreparation activity for plant protection

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INTRODUCTION

Biological preparations (biopesticides) based on natural biocontrol agents are a good alternative to synthetic chemicals in modern plant protection, especially in organic crop production. The merits of biological formulations of microorganisms and its metabolites are well known. Nevertheless, the use of biopesticides for protection of agricultural crops is not as widespread as desirable. Some explanations of this situation include narrow spectrum of host pest, more variable efficacy and field stability than chemicals. The aim of this presentation is to overview our previous and latest research and to show the possibilities of the enhancement of biopreparations activity for crop protection in some examples.
The experiments were carried out under laboratory and field conditions. Biopesticides of different origin were tested against insects of several orders and against phytopathogenic fungi. Some common methods for evaluation of efficacy of biological formulations for plant protection were described earlier (Shternshis et al., 2002; 2006).

RESULTS

In order to activate penetration of biological agents, such as baculovirus or Bacillus thuringiensis (Bt) into host targets, microbial chitinase (0.5 mU ml-1) was used as an additive to microbial insecticides. The enhancement in activity of baculoviruses, including the Cydia pomonella granulovirus (GV) and Mamestra brassicae nucleopolyhedrovirus (NPV), caused by chitinase was shown to be greater than the enhancement in Bt activity under the influence of the same enzyme. This fact allows us to use virus preparation containing 10-fold less biocontrol agent in the presence of chitinase against C. pomonella (Lepidoptera: Torticidae) in the Novosibirsk and Krasnodar regions of Russia. The results obtained in both regions showed the same efficacy of the traditional GV formulation (3 × 109 granule per ml) and the new one (3 × 108 granule per ml). To overcome the narrow spectrum of activity of some bioinsecticides, especially viral ones, mixture with other biological agents is useful. Taking into account the previous results concerning synergistic effect of Bt and M. brassicae NPV used together for cabbage protection, we developed the triple mixture consisting of Bt, M. brassicae NPV and chitinase (Shternshis et al., 2002). Such triple mixture provided complete protection of cabbage against all lepidopteran insects. In some cases, formulations based on natural microbial metabolites could replace both synthetic chemicals and microbial insecticides based on propagules. The application of such formulations allows to avoid some negative environmental factors and to achieve quick effect concerning plant protection. Therefore, we applied bioinsecticide based on natural Streptomyces avermitilis metabolite for vegetable and soft fruit protection in both field and greenhouse. The results showed that this formulation provided a good crop protection against several insects, such as beet webworm Pyrausta sticticalis (Lepidoptera: Pyralidae), raspberry cane midge Resseliella theobaldi (Diptera: Cecidomyiidae) some species of aphid, and against two-spotted spider mite (Tetranychus urticae) (Acari: Tetranychidae). In addition, this commercial formulation appeared to be a dual function biopesticide. Namely, in laboratory and field testing, the formulation recommended so far for insect control suppressed the growth of the phytopathogenic fungus Didymella applanata that causes raspberry spur blight. The efficacy of this S. avermitilis metabolite and synthetic chemical traditionally used against raspberry spur blight was shown to be similar:.

Table 1. Effect of S. avermitilis metabolite on raspberry spur blight severity (2001–2002).

Treatment	Spur blight surface severity (%)*	
	2001	2002
S. avermitilis metabolite 0.2%	19	13.8
S. avermitilis metabolite 0.1%	21	11.4
Chemical standard 0.1%	11	9.8
Control	46	21.4
LSD ($P = 0.05$)	6.6	6.6

* Spur blight surface severity means the damage to epidermis, parenchyma and periderm.

DISCUSSION AND CONCLUSIONS

There is no doubt that crops grown all over the world require ecologically safe pest control. Particularly, it concerns vegetable and berry crops, to avoid chemical residues in fresh fruits. The use of natural agents for pest control promotes the biodiversity of other natural enemies useful for insect and plant disease control. Although, in some cases, biological formulations were started for crop protection several decades ago, application is still in its infancy. Some observed disadvantages in the use of biopreparations could be reduced by enhancing their potency with one or more additives. Mixtures combining biocontrol agents with low concentrations of ecologically friendly components are more preferable to enhance biocontrol activity. Disadvantage in the practice of baculovirus-based formulation concerning its narrow spectrum of host could be reduced by addition of Bt-formulation based on synergistic strain. In some cases, the microbial metabolite formulations have some advantages over living organism-based preparations. Metabolites are less susceptible to environmental factors such as temperature, humidity and UV-radiation. Metabolite preparations also appear to have a wider spectrum and quicker action. Also, metabolite-based pesticides are environmentally safe and are not subject to accumulation in fruits as compared with synthetic chemicals. In addition, dual properties of these products concerning both insect and disease control observed in some cases, are rather valuable for plant protection.

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FRIS – best practice in viticultural disease and pest management in the Franconian wine-growing region

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INTRODUCTION

Database information systems have become fundamental for economic decisions in agriculture and horticulture. Also, in viticulture, such an information system can be helpful. To support local winegrowers the so-called FRIS (FRanconian Information Service for plant protection in viticulture) has been established since 1996 in the Franconian wine-growing area, located along the river Main. The focus of FRIS is to provide information for making individual decisions on pest management, involving a sound handling of resources and sustainable development in viticulture. Therefore, the system should provide highly up-to-date information and, at the same time, be adaptable to different microclimates and soil conditions in Franconia. All persons involved in viticultural advisory services in Franconia are involved and cooperate in FRIS. Thus, different or inconsistent recommendations (as sometimes happened in the past) are avoided.

STRUCTURE OF FRIS

FRIS is in structured into three parts: data collection, data processing and transfer of information.

Collecting data

Information concerning phenology of the vines and weather, as well as the occurrence of pests and diseases, is collected from four different sources: monitoring fields, reports of vineyard custodians, own field trials, and a network of 16 meteorological stations spread all over Franconia. At the heart of FRIS are five selected vineyards, representing the different soil and micro-climate conditions typical for the Franconian wine-growing region. These are monitored regularly (i.e. once a week within the growing season) by a qualified viticultural technician, for the presence of about 20 diseases, pests and important beneficial insects. In addition, we utilize the results of field trials conducted by the scientists of the Bavarian State Research Institute for Viticulture and Horticulture. Furthermore, vineyard 'custodians', located in almost every village of Franconia, report weekly about disease and pest development in their vines. These custodians are winegrowers, who act as representatives from all Franconian wine-growing villages, and are recommended for appointment by local winegrowers' associations. They act as mediators between research, winegrowers and advisory services. Being trained regularly by scientists of the Bavarian State Institute for Viticulture and Horticulture they provide helpful information for FRIS. Finally, the 16 meteorological stations record crucial data such as temperature, precipitation, humidity and leaf wetness. This ensures the high quality of information and, subsequently, of recommendations based upon FRIS.

Processing data

Data processing is done at the Bavarian State Research Institute for Viticulture and Horticulture. Information is compressed and transmitted to charts and graphics. Epidemiologic forecast models are then used as available. Results obtained by the different sources are also discussed and interpreted.

Transferring information

All information is transferred to winegrowers by all existing media. The 'Viticulture Fax Franconia' is issued twice a week by fax and e-mail and placed on the internet. It provides the latest information for winegrowers, e.g. timely information on specific pest development or a recommendation to use a certain method of pest control.

In addition, there is a Newsletter that provides up-to-date information on viticulture in general. Published monthly, all members of the Franconian Viticultural Association (c. 4,200 winegrowers from Franconia, including all cooperatives), get information about winegrowing, pest management, oenology and administrative regulations.

The annually published 'Guideline of Grapevine Pest Management' gives background information about pests and diseases. It considers all the climatic and geographical characteristics of the Franconian wine-growing region. Moreover, this free booklet contains a list of pesticides recommended for sustainable viticulture. Selected by the scientists of the Bavarian State Research Institute, and based on results of field trials, only those pesticides that do not harm beneficial insects are listed. The annual edition (with a circulation of more than 4,000 booklets) ensures that every interested winegrower can obtain information on environment-friendly methods of grape production. Besides the printed product, an internet version can be downloaded from the world wide web (http://www.lwg.bayern.de/wein-bau/rebschutz_lebensraum_weinberg/16334/).

RESULTS AND CONCLUSIONS

For more than 10 years, at the same sites, weather, plant growth, and epidemiology of diseases, pests and their antagonists have been monitored. This systematic and continuous sampling of uniform data has led to the establishment of a long-term data pool. Thus, a very helpful source of information has been established for new management practices and prognosis models. It is also a useful indicator for newly appearing diseases and pests.

FRIS is accepted very well by local winegrowers. In the meantime it is almost unthinkable to produce grapes in Franconia without information from FRIS. Not only do winegrowers and producers rely on its recommendations, but agricultural traders and representatives of agrochemical companies also use the information provided by FRIS and, thus, improve their sales. When thinking about best management practices in viticulture, FRIS represents the state of the art, at least within Germany.

Documentation of pesticide applications in arable farming – a study on German farmers' experiences and approaches

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INTRODUCTION

In Germany, recording of pesticide applications came into farmers' practice following the last official revision of the guidelines for good agricultural practice (GAP). These guidelines demand detailed documentation of pesticide measures taken. The recent plant protection act does not make documentation mandatory, but there is a demand for consideration of GAP. In fact, EU legislations 178/2002, 852/2004 and 183/2005 require documentation of the complete agricultural process chain, including plant protection. Additionally, in many cases, documentation of pesticide use and application data is already required by traders, millers, process labels and contract partners. Thus, farmers are forced in several ways to fulfil proper documentation. Nevertheless, critics of pesticide use argue that such documentation is insufficient and that misuse may still take place. Data are lacking, however, to evaluate the current state of agricultural practice in this area.

MATERIAL AND METHODS

An inquiry was carried out to obtain information on the implementation of documentation practices in arable farms. Accordingly, about 1,600 professional farmers in central Germany were contacted via a postal survey, which included questions about their documentation practices. This survey took place during June and mid-July 2006, before crop harvest. Participants were recipients of a plant protection and crop husbandry newsletter, issued by the official extension service in Lower Saxony (Niedersachsen). Questions asked related to technical issues and attitudes to statements. Responses were received from 36% of participants, which is quite a satisfactory proportion from a methodological viewpoint for socio-economic studies. The mean farm size of the respondents was 160 ha, which was above the average size (c. 50 ha) for farms in Germany.

RESULTS

All of the participants declared being involved in pesticide documentation. This is not surprising since those who refuse documentation would probably also have refused answering! Thus, the study cannot account for total share of documentation, but it can describe farmers' approaches. Pencil-written documentation (e.g. calendar books and field records) was still commonplace, and used by 45% of the farmers. Computer-based systems (e.g. PC-based field records, 'palm') were adopted by 55% of the sample. On average, farmers stated an annual expense of 582 € to maintain documentation equipment. Items documented are listed in Table 1. Consideration of items recommended by the German code of 'good agricultural practice in plant protection' is relatively high. However, the items 'name' and 'pest' may be considered infrequently since many farmers regard them as obvious. Optional data are considered less frequently in farmers' documentation.

Table 1. Items of pesticide documentation considered by German farmers (n = 581).

Item of documentation	Proportion of farmers (%)
Name *	37
Date *	98
Field identity, location *	94
Crop *	92
Pest *	24
Plant protection product *	97
Amount per ha *	94
Buffer zones etc. **	54
Crop growth stage **	53
Spraying technique **	38
Weather **	30
Treatment index **	9

* Recommended by code of 'good agricultural practice'. ** Optional items.

A cluster analysis of farmers' socio-economic statements identified four attitude groups with respect to mandatory documentation: 'opponents' (20%), 'those being afraid of farm checks' (20%), 'proponents on the farm level' (23%) and 'general supporters' (37%). The last-mentioned group sees documentation as an instrument for gaining acceptance by retailers and the public.

DISCUSSION

On-farm pesticide documentation by farmers is widely adopted and is carried out in a professional way. In Germany this is due to other reasons than national pesticide law. For far too long, mandatory documentation has been discussed at a political level and, in the public view, this could be seen as reservation by lobbyism. Farmers are recommended to be open and straightforward, to underpin their achievements, as is already stated by 'general supporters'.

Habitat and resistance management in renewable energy crops and set-aside land

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INTRODUCTION

In the last two decades the character of farming in the EU has changed from subsidized food and feed production into sustainable management of the farmland. Set-aside schemes or fallow periods were implemented as a control mechanism to reduce over-production and to stabilize prices for the crops and, more, recently as a regeneration strategy for the soil. Plant protection measures have always played a major economic role, to bring fallow land back into culture, to increase yields or as insurance of the harvest. Following several International Conventions the use of biomass for energy production or rising energy costs make farming of renewable energy crops more economical and necessary. In 2005 the world produced c. 40 million tonnes of bio-ethanol and bio-diesel. The main source is from processed plant oil and sugar. Escalating demand of energy will require biomass of complete plants to be converted to bio crude oil and methanol.

In Germany, grassland, maize, wheat and oilseed rape are used increasingly beyond their original destination for food production. Habitat and resistance management in renewable energy crops is an optimization tool of plant production techniques, and seriously needs to be taken into account when political or economical reasons ask for it.

HABITAT MANAGEMENT IN RENEWABLE ENERGY CROPS AND SET-ASIDE

The agro-ecosystem is a multi-zonal network of biotopes. Various levels of cultivation are directed by the farmer and he creates different habitats. Set-aside or fallow land can develop 30 to 80 different plant species within the first few years. Therefore, it is of considerable ecological importance, and can be used in the rotation (Knauer, 1993). Arable crops such assugar-beet, cereals, oilseed rape and maize can be used as alternative sources for renewable energy. However, the habitat or field must be managed similarly to conventional methods of arable farming to achieve highest yields. More and more silaged pasture grass is used in biogas plants as a substrate for co-fermentation, and fermentation is most effective when the C/N ratio is optimal. Highest yields of methane are achieved with silaged grass harvested from intensively managed pasture (Lemmer & Oechsner, 2003).

However, in terms of high floral species diversity of a landscape, it is acknowledged that fallow land, grassland, range and pasture are the closest to natural vegetation. Soil conditions and climate have determined floral distribution, plant community, frequency, status and level of establishment. Cultivation or melioration measures have produced habitats with a different proximity from nature. Moreover, increasing effects of biological globalization become evident in a shift of the floral composition, to the advantage of many exotic species (Hoffmann, 2005). Invasive alien species represent one of the primary threats to biodiversity.

For economical reasons the pasture destined as a source for renewable energy requires a culture of monocotyledonous grass species. Additionally, habitat management needs to avoid neophytes or invasive species, toxic or allergy-inducing weeds such as giant hogweed (*Heracleum mantegazzianum*), ragweed (*Ambrosia artemisiifolia*), ragwort (*Senecio jacobaea*) and japanese knotweed/bistot (*Reynoutria japonica* and *Fallopia sachalinensis*), to reach unacceptable levels of abundance on the fallow land ready for re-cultivation. Traditional pasture management tools of cutting or grazing may not be successful, especially when perennial weeds such as creeping buttercup (*Ranunculus repens*), broad-leaved dock (*Rumex obtusifolius*), creeping thistle (*Cirsium arvensis*), common nettle (*Urtica dioica*) are dominant and succeed the grass species. Specific active ingredients with herbicidal mode of action (Table 1) can control tricky weed species.

Table 1. Weed Control at rates registered in Europe.

Herbicide	*Ambrosia*	*Cirsium*	*Heracleum*	*Ranunculus*	*Rumex*	*Senecio*	*Urtica*
aminopyralid	98%	96%	–	93%	94%	99%	–
clopyralid	–	90%	–	–	–	–	–
triclopyr	–	–	100%	87%	70%	–	100%

RESISTANCE MANAGEMENT IN RENEWABLE ENERGY CROPS

Oilseed rape has been discovered as a major source for bio-fuel and is grown on c. 500,000 ha of set-aside land in Germany. Traditionally, in NW Europe, oilseed rape is part of a crop rotation with winter wheat and winter barley. Blackgrass (*Alopecurus myosuroides*) can be present in all three crops and, in some areas, may have already may have developed resistance to herbicides. The occurrence of graminicide resistance and cross resistance is of major significance to both current and future weed control programmes. Herbicide and insecticide resistance jeopardize expectations of high yield in oilseed rape. Non-specific-acting herbicides may preserve the efficacy of specific-acting herbicides against blackgrass, and suitable active substances, e.g. glyphosate, propyzamide and trifluralin, allow long-term, consistent 98% control as part of a herbicide resistance-management strategy in a narrow crop rotation. In 2006 some areas of Germany experienced total yield loss as result of attacks of pollen beetle (*Meligethes aeneus*). Predictable yield expectations for oilseed rape will require resistance-breaking insecticides (e.g. chlorpyrifos), since some pyrethroides already exhibit limited levels of control. Trials in Germany with chlorpyrifos have shown high levels of control of pollen beetle

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IPM in a developing country: Turkey's experience

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INTRODUCTION

Agriculture plays vital role in Turkey's economy and social life, over one third of the population living in rural areas and being employed in the agricultural sector. The area under cultivation in Turkey is 27 million ha, which represents 35% of the total land area. Turkey's geographical, climatic and agro-ecological diversity reflect her crop pattern. Wheat is grown throughout the country, but tea plantations occur only in northern Turkey (which is a humid area and where temperatures are mild). Crops produced in Turkey range from subtropical crops (such as banana, kiwifruit and tea) to winter cereals, the foremost crops being wheat, barley, corn, pulses, cotton, sugar beet, potato, tobacco, sunflower, vegetables, pome and stone fruits, nuts, citrus fruits, grapes and olives. Differences in cropping patterns, geography and climate result in varying pest and disease patterns in the different areas. For instance, the key diseases in vineyards are downy mildew (*Plasmopara viticola*) and powdery mildew (*Uncinula necator*); the key pests in grain crops are shield bugs (*Eurygaster* spp.) (Scutelleridae) or wheat bugs (*Aelia* spp.) (Pentatomidae), depending on the growing region.

Turkish agriculture is different from that of under-developed and developed countries. More than 65% of agricultural enterprises are of 5 ha or less. The use of tractors is increasing and man/animal power is decreasing. Currently, there are over one million tractors and ploughs but fewer than 100,000 animal-powered tools for ploughing. Hand-hoeing in cotton production is reduced to once per season and replaced by inter-row tillage with tractor-powered machinery. Pesticide use in Turkey, however, has been increasing (from c. 8,000 t in 1979 to > 13,000 t in 2004). However, the amount of pesticide used varies from region to region. Although pest resistance to pesticides has not been well documented, some cases of resistance have been reported and studied in Turkey. Alternative methods, such as biological control and systems such as ecological agriculture and integrated pest management (IPM), have been implemented.

IPM IN TURKEY

Biological control of pests started in Turkey in the early 1900s, and the first IPM research project began (in cotton) in 1970. This project was followed in 1972 by others, to establish IPM on apple and hazelnut. The results were applied in the field soon afterwards, and spraying against insects in cotton fields, for example, dropped from 10–11 applications to 4–5. Forecasting and warning systems were established for codling moth (*Cydia pomonella*) and scab (*Venturia inaequalis*) in the early 1980s. A cornerstone of IPM in Turkey is that, in 1990, projects were implemented by the Ministry of Agriculture in 10 main crops: apple, cherry, cotton, hazelnut, maize, olive, pistachio, potato, sunflower and protected crops (vegetables and ornamentals). These projects mostly focused on collating earlier data and producing new data, to establish IPM programmes. They were conducted by researchers in the main production areas of each given crop. Extension agents were trained as well as researchers. Projects covered not only insect pests but also diseases, physiological disorders and weeds. Results of these projects and the future of IPM were discussed at a meeting held in 1994. The meeting was considered one of the most important steps in IPM in Turkey, because new attitudes to IPM were established. Goals, objectives, policy and strategies, that had been determined in 1988, were revised. The name of the umbrella project was changed (from the '*National research, development and training project for IPM*' to the '*National research, implementation and training project for IPM*'), which resulted in active and greater involvement by extension agents and producers. Following the meeting, IPM in Turkey became applied in the field instead of merely remaining a theory within research institutions. The number of crops under IPM was increased. Apricot, chickpea, citrus, lentil, peach, grapevines and wheat were added; the protected crops project was restricted to vegetables; and the sunflower project was cancelled. IPM was added to the national pest management programme book in 1997, and *'Directives for IPM Projects'*, which covers responsibilities of all stakeholders and project implementation methods, was published in 1999. After 2000, IPM activities were mainly implemented by extension agents, although researchers and research institutions kept their involvement as trainers and regional coordinators. New crops, such as rice, bean, pear and walnuts, were added. Some crops, such as soybean and sunflower, were added but then cancelled. Some universities conducted their own IPM projects independently, but they produced only data for research fields belonging to participating farmers and some training material. Currently, over 2,000 ha area is under IPM; although an additional 6,000 ha is ready for developing IPM for potato mildew (a very small percentage of both the chemically sprayed area and the total arable area). IPM in fruit crops covers 127,500 trees (including apple, cherry, peach, apricot, pear, sour cherry, walnut, pistachio, hazelnut, citrus and olive). The forecasting project for apple covers over 12 million trees (out of 42 million), and that for vineyards is implemented on 130,000 out of 560,000 ha. However, the area/tree where IPM has been implemented has not increased for a decade.

The projects resulted in pesticides in Turkey being classified according to their toxicity and impact on the environment. IPM guidelines have been prepared for citrus, apple, grapevines, cotton, chickpea, potato, peach, olive, cherry and protected vegetables (cited here in the order of the publishing year), and these are available in hard copy and on the internet.

Regrettably, IPM in Turkey has been adopted in only limited areas, in spite of farmers and extension agents having been trained. After 15 years of intensive IPM projects, pesticide use continues to spread, and implementation of IPM is not recognized by administrators; also, vast numbers of farmers are not aware of IPM. There are many bottlenecks, but the main one is the lack of awareness of environmental issues. Additionally, lack of consumer education and market-related activities are among the most important weak points of the projects. These projects are only one step back from integrated crop management; however, new data on different subjects (such as pesticide resistance, pest/environment relations, novel methods, and thresholds) should be produced to improve IPM. Turkey's experience can be used by many countries, as well as by herself.