Biological control of plant diseases

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1. Introduction

Biological pest control provides an important route to environmentally harmless plant protection (Diercks, 1983). This route reduces risks, e. g. of becoming aware too late of unfortunate side effects of plant protection agents. Thus there are examples of side effects of fungicides which, applied regularly, wipe out the ground beetle population of a field within 12 years (Basedow, 1991). Intense use of active substances can harm beneficial organisms and sometimes even promote pests. In apple orchards it was quickly found that a benzimidazole fungicide kills earthworms in the soil and hence indirectly encourages infestation with apple scab in the following year (Niklas and Kennel, 1981). Because there are no alternatives this fungicide is still used, even though many harmful fungi have become resistant to it. Despite all the efforts the quantities of plant protection agents that are applied are scarcely diminishing (Gemmeke, 1991). In apple orchards the fungicide application rate is often still 30 kg/ha per year. This is astonishing when one considers that both old and new text books (Bruehl, 1975; Schippers and Gams, 1979; Cook and Baker, 1983; Philipp, 1988; Krieg and Franz, 1989) give many examples of biological control of insects and fungi. Systems that function well against insects already exist but the situation with regard to control of phytopathogens, particularly fungi, is less favourable. There are only a few agents on the market (Lynch, 1988). This is difficult to comprehend when one reads in numerous publications the final sentence, "Laboratory and field studies have shown that organism X is eminently suitable for control of pathogen Y." Why then have biological agents attained a market share of less than 0.5% of the total plant protection market? Why is this market share even smaller where agents for the control of fungal diseases are concerned? And how can this situation exist when the first studies of the biological control of fungal diseases date from the thirties (Philipp, 1988).

The essential reason is surely that it is much easier to control fungi with fungicides. These active substances can be used against various fungi on various parts of the plant. Biological systems, by contrast, are very specialized. Fungi that e. g. parasitize a specific root region occupy a niche there. To control such a fungus or its dormant structures, a beneficial fungus that is to be used to attack the harmful fungus must be capable of competing for this niche. Such precisely adapted systems are not only difficult to produce but are incapable of great commercial success because opportunities for their use are limited (Reinecke et al., 1991). Below we give some examples of these problems and discuss some methods of activating the plant's own defence mechanisms against parasites, these methods representing a further alternative to fungicides.

2. Biological control in soil

At first sight the favourable conditions for fungal growth make biological pest control in the soil seem very promising. For insects that move actively in soil, and are thus very likely to come into contact with an entomopathogenic fungus incorporated into the soil, there are systems that are already enjoying commercial success (Reinecke et al., 1991). The use of beneficial fungi against pathogenic fungi is very much more difficult, however, because it is extremely difficult to distribute the beneficial fungus uniformly through the inert, virtually immobile soil system (Gisi et al., 1990). It must therefore be applied in large, relatively unwieldy quantities if it is to inhibit the infective pathogen. Application rates of 6000 kg/ha are not uncommon (Adams, 1990). This is just as true when substrates for beneficial fungi, such as chitin, are added to the soil (Chet, 1990). Only such application rates can ensure that the population of the beneficial fungus is dense enough to produce a reliable effect. To achieve control economically, Adams (1990) recommends carefully designed cultivation taking full account of the requirements of the beneficial fungus. Regular spraying is not enough; it simply perpetuates the old "fungicide mentality". The control measures must be matched to the individual soil type. Local soil conditions such as pH, temperature, and organic and inorganic components must be taken precisely into account. In the control of Fusarium wilt with nonpathogenic strains that compete with the pathogenic strains for the same niche (Mandeel and Baker, 1991), success was actually achieved by treating the roots in small bundles (Mattusch, 1990). A precondition here, however, was that the infection pressure was not too high and, owing to the large application rate, only relatively small vessels had to be treated. The much prized beneficial fungus *Trichoderma harzianum* or *koningii* is probably reliable only as a seed treatment (Nelson et al., 1988).

More promise seems to be offered by the use of mycorrhiza fungi, which colonize the roots of their host plants under natural conditions and, on reinforced use, suppress many phytopathogenic fungi (Dehne, 1982). Some ectomycorrhiza fungi are actually capable of actively lysing phytopathogenic fungi (Kope and Fortin, 1990). Methods have been developed of binding mycorrhiza fungi to bloated clay and sowing the resulting granules together with the seed (Dehne and Baltruschat, personal communication). A similar product is already on the market (Nutrilink®). High costs currently restrict its use to particularly profitable crops.

The role of soil bacteria as beneficial microorganisms must not be overlooked. Fluorescent pseudomonads are a natural component of the microbiocoenosis and compete with many harmful fungi and bacteria. If appropriate cultivation measures that encourage the growth of fluorescent pseudomonads are employed, an effective biological control system can be established in the soil (Gutterson, 1990). Here too, however, seed treatment is probably the more reliable course (Weller and Cook, 1983). Similar strategies are employed to control *Agrobacterium tumefaciens* on young plants (Kerr et al., 1990). *A. radiobacter* strain K 84 which is used for that purpose has now been improved using genetic engineering methods.

3. Biological control on leaves and fruit using fungi and bacteria

The situation on leaves and fruit is very different compared to the situation in soil. During the growing period numerous bacteria, yeasts and other fungi grow on the leaves of the plants (phyllosphere). About 105 microorganisms per cm^2 leaf surface are observed (Fokkema and Schippers, 1986). These microorganisms live on nutrients exuded by the leaves, on dust or pollen deposits, and on insect excreta. They multiply rapidly under favourable, humid conditions and their numbers decline under unfavourable conditions such as persistent sunshine. Most of these microorganisms are relatively neutral for the plant: they are of little use to it, but they do not harm it. Only at high densities is a slight impairment of yield observable (Smedegaard-Petersen and Tolstrup, 1986). Relatively neutral fungi, the endophytes, are also found inside the leaves (Petrini, 1991). Their importance has not yet been adequately investigated. They seem to interact with organisms such as siderophores (Fokkema and Schippers, 1986; Leong, 1986). By excreting poisons they deter insects that infest plants (Clay, 1989; Wulf, 1990). However, their hormone production also influences the host plant. It is possible that such microorganisms activate defence reactions in the plants, thus impeding infection by phytopathogens. This offers a new strategy for biological pest control.

The influence of the normal leaf flora on a pathogen of apple rot, *Botrytis cinerea*, is shown in Fig. 1. Many of 397 isolates found on apple leaves show a distinct influence on the sporulation of *B. cinerea*. This work was a screening study to identify fungi or bacteria which attack and lyse the pathogen or secrete an active substance which inhibits its growth. A beautifully investigated example is *Verticillium lecanii*. This fungus is capable of infecting the spores of rust fungi (Hassebrauk, 1936) and mildew fungi (Heintz and Blaich, 1990) and also a very wide range of insects (Schuler et al., 1991). It therefore seems predestined for biological control with a broad range of uses. However, despite innumerable publications on the efficacy and good properties of this fungus its use in practice is still negligible. Despite undisputed successes in individual cases it repeatedly suffers failures that are unacceptable to a commercial user. This inconsistency is due to the high demands of *V. lecanii* with regard to humidity (Mendgen, 1983). Whereas phytopathogenic fungi, as part of their survival strategy, can penetrate the plant within a few hours in order to escape from the dry period of the daily cycle, *V. lecanii* cannot. As a result, uniform growth and regular sporulation cannot be guaranteed. The hyperparasite constantly lags behind its prey. To improve the situation, the blastospores of *V. lecanii* were formulated with carbohydrates for use against rust fungi (Grabski and Mendgen, 1985) or with phospholipids for use against aphids (Pfrommer and Mendgen, 1991) so as to achieve better growth. Really good results are probably possible only in tropical regions, however (Saksirirat and Hoppe, 1990).

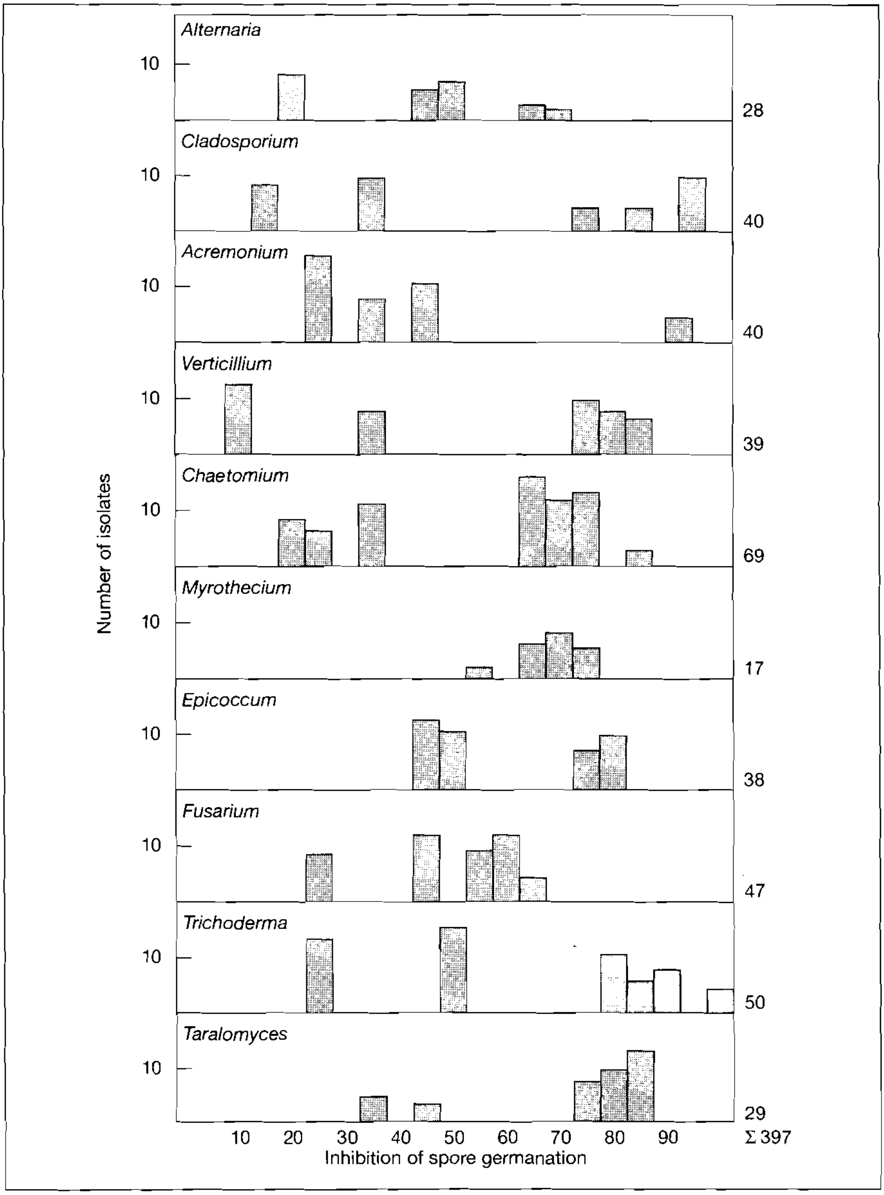

Fig. 1: Inhibition of sporulation of *Botrytis cinerea* Pers. Ex. Fr. by 397 fugal isolates from varius genera found on apple leaves.

Similar problems arise in the control of powdery mildew on cucumbers (*Sphaerotheca fuliginea*) with the hyperparasite *Ampelomyces quisqualis*. The importance of this fungus was recognized as long ago as 1852. The first control studies were performed in 1932 (Philipp, 1988). Skilful cultivation in greenhouses succeeded in reducing the cucumber mildew considerably (Philipp and Hellstern, 1986). Unlike other biological products, however (see Section 4), this system has not proved viable. The demands of the hyperparasite on its environment are too special and the overlap of the optimal conditions for the two fungi *S. fulginea* and *Ampelomyces quisqualis* is too narrow. In practice the conditions for growth of the hyperparasite had to be improved by making a fundamental change in the cultivation of the cucumbers, i. e. by growing them at high humidity.

In recent years the control of apple diseases has seen particularly big efforts to use biological methods because in the Lake Constance area, for example, more than 20 sprayings per season are often used against apple scab alone. Moreover, biological alternatives seem particularly promising because numerous antagonists to the pathogen, *Venturia inaequalis*, can be isolated (Andrews et al., 1983). A particularly good effect has been obtained with *Athelia bombacina* and *Chaetomium globosum* (Heye and Andrews, 1983). The treatments of the leaves in the course of the growth period were unsuccessful, however, because the active substance(s) of the beneficial fungi is/are degraded too rapidly on the leaf surface (Boudreau and Andrews, 1987). Since infestation with *V. inaequalis* is heavily dependent on airborne spores in spring (Gadoury and MacHardy, 1984), an attempt was made to combat the ascospores or pseudothecia in the leaves. In the course of the winter *A. bombacina* and *Ch. globosum* colonize about 85% of the apple leaves lying on the ground (Young and Andrews, 1990). After use of an improved formulation in the Lake Constance area the efficacy in reducing ascospores was 60–70% for *Ch. globosum* and actually 100% for *A. bombacina* (Miedtke and Kennel, 1990). Further field studies are in progress to clarify whether the infection of the leaves on the tree with *V. inaequalis* in the spring can be reduced correspondingly (Kennel, personal communication).

In the control of storage diseases of apples the efficacy of fungicides is limited and the use of certain active substances is questionable on health grounds (Pusey, 1989). A biological treatment that could replace the usual two final sprayings would therefore be particularly helpful. Moreover, numerous microorganisms with suitable properties occur naturally on apple leaves (Fig. 1). Their use against apple rot seems promising because controlled conditions favourable to the antagonists can be maintained in the warehouses. In identifying and selecting suitable microorganisms, however, it must be borne in mind that storage rots can be caused by more than one pathogen. It is difficult to select a single microorganism that is active against various pathogens. Some bacteria, such as *Pseudomonas cepacia* and *Bacillus subtilis*, control *Botrytis cinerea* and *Penicillium expansum* fairly well at 24 °C (Pusey and Wilson, 1984; Janisiewicz, 1987; Janisiewicz and Roitman, 1988). The active substances pyrolnitrin

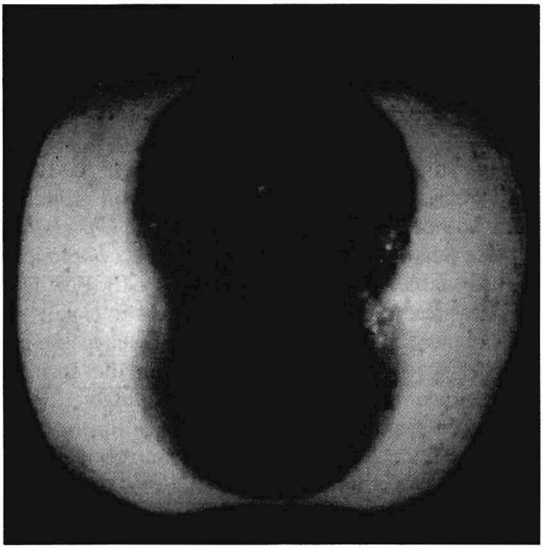

Fig. 2a: Rot symptom after wounding and infection with *Botrytis cinerea* Pers. (2×10^3 spores/20 µl). Golden Delicious apple, incubation for 3 weeks at 4 °C.

and iturin have been isolated from *P. cepacia* and *B. subtilis* respectively (Pusey, 1989). Candida yeasts (McLaughlin et al., 1990) and *Cryptococcus laurentii* (Roberts, 1990) also show good efficacy. *C. laurentii* grows at 5 °C, which approximates to the storage conditions. *Acremonium species* (Figs. 2a, b) are also effective in cool stores. Against the other pathogens of apple rot, *Pezicula malicorticis* and *Nectria galligena*, bacteria and fungi have similarly been found that can reduce the development of rot at 20 °C. These are much less effective at 4 °C, however (Fig. 3). Thus application of these microorganisms directly before storage of the fruit would be unhelpful and they must therefore be applied in the field, i.e. at the final spraying, so that they can multiply

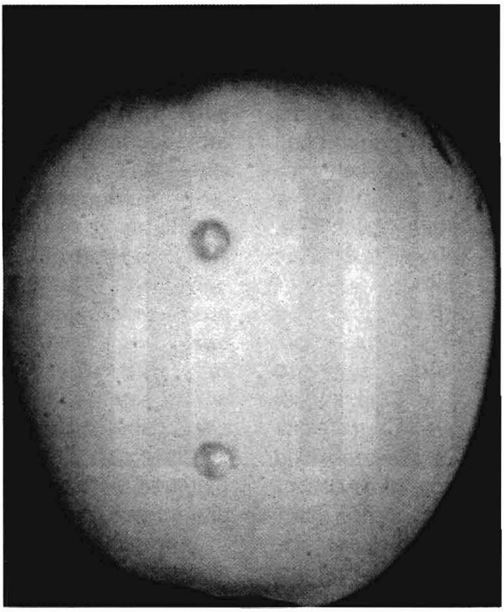

Fig. 2b: Symptom after pretreatment with *Acremonium* sp. (2×10^5 spores/20 µl) followed (1 day later) by inoculation with *Botrytis cinerea* Pers. as above.

under field conditions. A study under commercial conditions in collaboration with the Bodenseeobst Fruit Marketing Cooperative is currently in progress. Furthermore an attempt is being made to isolate the active substance of a beneficial fungus (Fig. 3; Schiewe and Mendgen, 1991) because this reduces the development of rot at low temperatures too.

4. Agents that strengthen the plant's own defences

Starting from the observation that plants can fend off pathogenic fungi under certain conditions, active substances are now being sought which, although they possess little or no toxicity towards fungi, stimulate the defence reactions of plants (Patrick, 1986; Klingauf and Her-

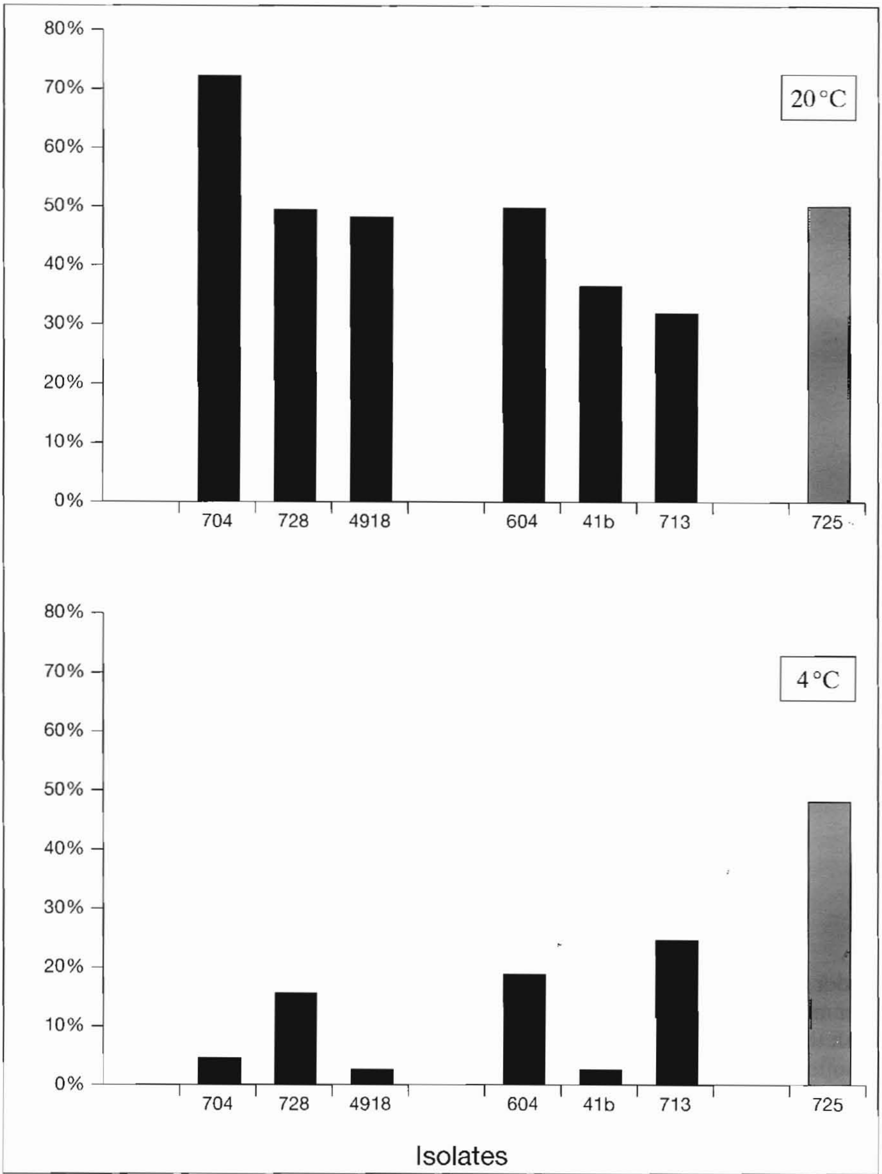

Fig. 3: Control of the storage rot pathogen *Pezicula malicortis*. Reduction of rot (in %) by three bacterial isolates (704, 728, 4918), three fungal isolates (604, 41b, 713) and culture filtrate of fungal isolate 725.

ger, 1990). Such active substances, also known as inductors, were first obtained from culture filtrates of various bacteria (Schönbeck and Dehne, 1986). However, this principle of biological plant protection is usually only effective when the plants have already been treated before infection by the pathogen. The plants can then initiate the appropriate defensive metabolism at an early stage. Numerous parasites, mostly biotrophic fungi, have been successfully treated in this way. Inductor treatments evidently not only modify the host-parasite relationship (Steiner et al., 1988) but also influence the performance of the crop with regard to yield (Oerke et al., 1989). Plants treated with inductors give a high yield, similar to that obtained after fungicide treatment, despite the residual infestation with the parasite.

Other agents, such as compost extracts (Winterscheidt et al., 1990) or other organic material (Becker et al., 1990), are still very ill-defined. This is undoubtedly one reason why studies with these agents do not yet show good reproducibility. It is therefore important to characterize the active substance(s).

It is already possible to buy a "plant strengthener", Milsana®, consisting of knotgrass (*Reynoutria sachalinensis*) leaves (Herger et al., 1988). Ethanolic and aqueous extracts (tea!) are effective against cucumber mildew (*Sphaerotheca fuliginea* and *Erysiphe cichoracearum*), if used protectively and very regularly. Here too it is important to investigate the action mechanism because it is still unclear why tea should be so effective against cucumber mildew. Individual components do indeed seem to affect the pathogen directly (Gisi, personal communication).

Another "alternative" product, Myco-San®, contains aluminium sulphate, wettable sulphur and other constituents such as horsetail extract, yeast and silica. Ulmasud® is a refined clay mineral consisting of silica, aluminium dioxide and titanium dioxide. Both products are capable of controlling powdery and downy mildews. As regards their action mechanism, certain components may act directly on the fungus whilst others, such as clay minerals or silica, may impede recognition of the plant surfaces that some fungi need for infection or may stimulate the plant's defences. In downy mildew on vines (*Plasmopara viticola*), however, these products do not represent a feasible alternative to the existing copper treatment (Kast, 1988; Färber et al., 1991). Against apple scab the effect is comparable to that of sulphur (Haseli and Bosshard, personal communication). Although Ulmasud and Myco-San are no replacement for conventional fungicides, they do have a role in "alternative" agriculture because an adequate effect can be achieved in mild to moderate infections with certain fungi.

Good results against *Plasmopara viticola* and *Phytophthora infestans* have been reported after use of potassium phosphite (4.5–7.5 kg/ha) (Häseli and Graf, 1991, personal communication). This active substance, which is very cheap, seems to act not so much by activating the plant's defences as by attacking the fungus directly (Cohen, 1986). Attempts to induce a defence against the potato rot pathogen by treating the plants with various fatty acids (Cohen et al., 1991) or with fungal constituents (Heller and Gessler, 1986) could not be exploited commercially because consistent protection of the plants was not obtained.

Similarly well defined are derivatives of isonicotinic acid used to induce the plant's defences. Patents for these have already been granted. Field studies have demonstrated efficacy against fungal diseases (*Colletotrichum lagenarium* and *Peronospora tabacina*) and some bacterial diseases (Metraux et al., 1991). Owing to inconsistent results in practical use and phytotoxicity at low overdoses, however, these products are unlikely to be introduced commercially.

5. Summary

In the biological control of plant diseases, the coincidence of pathogen and useful microorganism constitutes a particular problem. The harmful microorganism generally has an advantage over the useful one. The useful microorganism therefore has to be applied in large amounts, and the growth conditions should be optimised for it. In addition to these difficulties, living microorganisms can give rise to allergies and often eliminate toxic metabolic products. Hence, the importance of biological control of plant diseases is always restricted to a few special cases where the biology of the pathogen and of the useful microorganism have been very carefully investigated beforehand (Mendgen, 1983). To give them a commercial chance, they should be correspondingly promoted at least at registration.

The use of active ingredients which activate the defence mechanisms of the plant seems simpler and more promising. However, only a few investigations are available to date, most of which were carried out with extracts and culture filtrates. Further studies are required here. These are at least as worthy of support as the programme, supported with an unusually large amount of money by the Federal Government, for isolating by molecular methods genes which are responsible for unspecific defence reactions of plants. There are already various, successful programmes of this type in industry (Hain et al., 1990; Roby et al., 1990) but experiments conforming to practice are still lacking. Moreover, these modern methods are still not so easy to apply in many crops. Unfortunately, the market for the so-called "biological" agents is very disorganised. They are generally sold as "plant strengthening agent" without further testing of their efficacy. Adverse side effects against useful microorganisms, which also occur here (Färber et al., 1991), are neglected or remain undiscovered. The legislator should play a guiding role here so that the introduction of biological control systems, which in practice encounters many obstacles and requires a great deal of persuasion (Albert and Meinert, 1991), can also be successful. An effective system which has demonstrated its advantageous influence on the balance of nature should be appropriately promoted by the legislator (Làngenbruch and Huber, 1990) by, for example, adapting the registration to the requirements in biological pest control and perhaps even simplifying them (Woodhead et al., 1990).

Zusammenfassung

Biologische Bekämpfung von Pflanzenkrankheiten

Bei der biologischen Bekämpfung von Pflanzenkrankheiten ist die Koinzidenz von Pathogen und nützlichem Mikroorganismus ein besonderes Problem. Der Schädling hat gegenüber dem Nützling meist einen Vorsprung. Deshalb muß der Nützling in großen Mengen ausgebracht werden, und die Wachstumsbedingungen sollten für den Nützling optimiert sein. Zu diesen Schwierigkeiten kommt hinzu. daß lebende Mikroorganismen Allergien hervorrufen können und oft giftige Stoffwechselprodukte ausscheiden. Deshalb ist die Bedeutung der biologischen Bekämpfung von Pflanzenkrankheiten immer auf ei- Sonderfälle beschränkt. bei denen die Biologie des Erregers und des Nützlings vorher sehr genau untersucht wurde (Mendgen, 1983). Um ihnen kommerziell eine Chance zu geben, sollten sie zumindest bei der Zulassung entsprechend gefördert werden.

Einfacher und vielversprechender scheint der Einsatz von Wirkstoffen. die die Abwehrmechanismen der Pflanze aktivieren. Bisher liegen aber nur wenige Untersuchungen vor, die meist mit Extrakten und Kulturfiltraten angefertigt wurden. Hier sind weitere Unter- nötig. Diese sind mindestens ebenso förderungswürdig wie die von der Bundesregierung mit ungewöhnlich viel Geld unterstützten Programme, mit molekularen Methoden Gene zu isolieren. die für unspezifische Abwehrreaktionen der Pflanzen verantwortlich 'InJ. Hier gibt es bereits verschiedene, erfolgreiche Programme in der Industrie (Hain et al.. 1990; Roby et al., pra- xisnahe Versuche fehlen jedoch noch. Außerdem sind diese modernen Methoden bei vielen Kulturpflanzen noch nicht so einfach anzuwenden.

Leider ist der Markt der sogenannten "biologischen" Mittel sehr unübersichtlich. Sie werden meist als "Pflanzenstärkungsmittel" ohne weitere Prüfung ihrer Wirksamkeit verkauft. Unerwünschte Nebenwirkungen gegen Nützlinge. die auch hier vorliegen (Färber et al., 1991), bleiben unbeachtet bzw. unentdeckt. Hier sollte der Gesetzgeber lenkend eingreifen, damit die Einführung biologischer Bekämpfungssysteme. die in der Praxis mit vielen Hindernissen und Überzeugungsarbeit verbunden ist (Albert und Meinert, 1991). auch erfolgreich sein kann. Ein wirksames System, das seinen günstigen Einfluß auf den Naturhaushalt bewiesen hat. sollte der Gesetzgeber entsprechend fördern (Langenbruch und Huber, 1990), indem er beispielsweise die Zulassung den Erfordernissen in der biologischen Schädlingsbekämpfung anpaßt und vielleicht sogar vereinfacht (Woodhead et al.. 1990).

Résumé

Lutte biologique contre les maladies des plants

Dans la lutte biologique contre les maladies des plantes, la coincidence de ragent pathogene et du microorganisme utile constitue un probleme particulier. L'organisme nuisible a presque toujours une avance par rapport à l'organisme utile. En consequence, il faut que l'organisme utile soit epandu en grande quantité et que ses conditions de croissance

soient optimisées. En plus de ces difficultés s'ajoute le fait que les microorganismes vivants peuvent causer des allergies et excrètent souvent des produits de métabolisme qui sont toxiques. C'est pourquoi l'importance de la lutte biologique contre les maladies des plantes est toujours limitée à certains cas particuliers où la biologie de l'agent pathogène et celle de l'organisme utile ont été étudiées préalablement très exactement (Mendgen, 1983). Pour donner une chance à ces agents, sur le plan commercial, ils devraient pour le moins être promus de manière appropriée pour l'homologation.

L'utilisation de matières actives capables d'activer les mécanismes de défense de la plante semble plus simple et plus prometteuse. Les études disponibles jusqu'à maintenant sont rares; elles ont été réalisées avec des extraits et des filtrats de cultures. D'autres études sont nécessaires à cet égard. Elles méritent tout autant d'être soutenues que celles qui le sont par le gouvernement fédéral, avec beaucoup d'argent, dans le but d'isoler par des méthodes moléculaires des gènes responsables de réactions de défense non spécifiques des plantes. Là, il existe déjà différents programmes qui ont été menés avec succès dans l'industrie (Hain et al., 1990; Roby et al., 1990), mais des essais proches de la pratique font encore défaut. D'autre part, ces méthodes modernes ne sont pas faciles à appliquer dans le cas de nombreuses plantes cultivées.

Le marché des produits dits «biologiques» est malheureusement très peu transparent. Ces produits sont vendus le plus souvent en tant que «fortifiants pour les plantes» sans étude plus poussée de leur efficacité. Des effets secondaires indésirables contre des organismes utiles, qui existent effectivement (Färber et al., 1991), demeurent ignorés ou ne sont pas découverts. Le législateur devrait intervenir de manière dirigiste dans ce domaine afin que l'introduction de systèmes de lutte biologique qui est liée à de nombreux obstacles et à un travail considérable (Albert et Meinert, 1991) puisse aussi être couronnée de succès. Un système efficace, ayant fourni la preuve de son influence favorable sur le bilan de la nature, devrait être soutenu de manière appropriée par le législateur (Langenbruch et Huber, 1990) en adaptant par exemple les conditions d'homologation aux exigences de la lutte biologique contre les parasites et peut-être même en les simplifiant (Woodhead et al., 1990).

Resumen

Control biológico de las enfermedades de las plantas

En el control biológico de las enfermedades de las plantas, la presencia simultánea del patógeno y del microorganismo benéfico constituye un problema especial. La plaga suele tener cierta ventaja de desarrollo frente al organismo útil, por lo cual éste ha de ser aplicado en grandes cantidades, debiendo enfrentarse, además, con condiciones de crecimiento óptimas. A todo ello debe agregarse que los microorganismos vivos pueden provocar alergias y que a menudo excretan productos metabólicos tóxicos. Por lo tanto, la importancia del control biológico de las enfermedades de las plantas queda limitada siempre a unos pocos casos especiales, en los cuales se examinaron previa y exacta-

mente la biología del agente patógeno y del organismo benéfico (Mendgen, 1983). Para ofrecerles buenas posibilidades a nivel comercial, tales productos deberían ser fomentados por lo menos en su registro.

El uso de ingredientes activos que estimulan los mecanismos de defensa de la planta parece ser más sencillo y prometedor. Sin embargo y hasta ahora, sólo se dispone de muy pocas investigaciones al respecto, la mayoría de las cuales se realizaron con extractos y filtrados de cultivo, por lo cual son necesarias investigaciones ulteriores. Estas merecen ser tan fomentadas, como los programas subvencionados con sumas extraordinarias por el gobierno alemán, destinados a aislar – mediante métodos moleculares – genes responsables de las reacciones de defensa inespecíficas de las plantas. Aquí, ya existen varios programas exitosos en la industria (Hain y cols., 1990; Roby y cols., 1990), si bien aún no se han efectuado experimentos con orientación práctica. Además, estos métodos modernos no pueden aplicarse tan fácilmente en muchas plantas de cultivo.

Lamentablemente, el mercado de los llamados productos «biológicos» es de muy difícil orientación. Estos preparados suelen venderse como «estimulantes de plantas» sin comprobación ulterior sobre su eficacia. No se atiende a o bien quedan sin descubrir los efectos secundarios indeseables existentes contra los predadores (Färber y cols., 1991). Aquí, debe intervenir el legislador para que la introducción de los sistemas de control biológico, la cual en la práctica se enfrenta con muchos obstáculos y exige grandes esfuerzos persuasivos (Albert y Meinert, 1991), pueda ser exitosa. Un sistema eficaz, que haya demostrado su efecto favorable en el equilibrio natural, también debe ser fomentado correspondientemente por el legislador (Langenbruch y Huber, 1990), en tanto que éste, por ejemplo, adapte el registro a los requisitos del control biológico de plagas o incluso simplifique los trámites pertinentes (Woodhead y cols., 1990).

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