SESSION 5

BIOLOGICAL APPROACHES TO THE DISCOVERY OF PEST AND DISEASE CONTROL AGENTS

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INVITED PAPERS 5-1 to 5-3

PLANTS AS SOURCES OF NOVEL PEST AND DISEASE CONTROL AGENTS

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ABSTRACT

There is overwhelming evidence that some of the secondary compounds synthesised by plants provide a chemical defence against animal herbivores and/or pathogens. Studies of naturally occurring polyhydroxy alkaloids (nitrogen sugars) have shown that individual secondary compounds may be highly specific in their interactions with particular insects and enzyme systems. It is suggested that the study of these and other secondary compounds may provide a deeper understanding of the structural requirements which must be met in molecules intended to disrupt the metabolic pathways of specific pest organisms without significantly affecting the host plant or man.

INTRODUCTION

During the course of evolution, plants have probably synthesised countless thousands of secondary compounds; i.e. compounds that are not essential to a plant's primary metabolic processes. It is highly likely that the great majority of such compounds proved to be a liability to the plants in which they arose and neither the plants containing them nor the compounds themselves have survived for our study. Occasionally, however, when a plant containing such a compound has survived and prospered, it may have been because of a selective advantage conferred by the presence of that compound. One such advantage may have been the protection of the plant from attack by animal predators or invasion by pathogens.

The whole process of plant evolution can be conceived of as a great biological screening process in which secondary compounds of extraordinary structural diversity have been tested against potential predators and pathogens over the course of thousands of years. I believe that we would be unwise to ignore the results of this long running experiment when seeking new approaches to the protection of crop plants.

While the significance to the plant of some secondary compounds, such as the flower pigments that attract pollinators, is fairly obvious, it is by no means clear that all secondary compounds have an ecological role. There is, however, irrefutable evidence that some secondary compounds do, as previously suggested, form part of the defensive screen by which plants are protected from herbivores and pathogens (Feeny 1983, Bell 1984). It is also apparent that the same secondary compound may be toxic to one organism and harmless to another, attractive to one and a repellant to another. These are factors which must be borne clearly in mind when considering the use of secondary compounds or synthetic variants in crop protection. The pyrethrins provide a good example of a group of compounds which is highly toxic to insects while relatively harmless to warmblooded animals, and the non-protein amino acid L-homoarginine, which accumulates in the seeds of many legume species, is toxic to the seed-eating larvae of the bruchid beetle Callosobruchus maculatus (Janzen et al. 1977) and the bacterium Escherischia coli but acts as a precursor of the essential amino acid lysine when fed to rats (Walker 1955). Clearly, the relative toxicity of secondary compounds and their derivatives to man and the "pests" that are in competition with him for the same food plants is an important one.

Less easy to establish than toxicity is deterrency but I would suggest that more effort should be directed to identifying the nature of plant compounds, or mixtures of plant compounds, that can protect by deterring rather than poisoning potential predators.

In the present paper I shall discuss these ideas with particular reference to insect predators and a recently discovered group of polyhydroxy alkaloids which have been the subject of interdisciplinary studies at the Royal Botanic Gardens and elsewhere.

TRADITIONAL INSECTICIDES FROM PLANTS

The pyrethrins from the flower heads of *Chrysanthemum cinerariafolium* have already been referred to and very successful synthetic analogues have been developed from them (Elliott 1983). Rotenone and related isoflavonoids derived from the legume genera *Derris* and *Lonchocarpus* have also been used for many years as insecticides, and recent research (Birch *et al*. 1985) suggests that the presence of rotenoids may protect the seeds of *L. salvadorensis* from attack by bruchid beetles. The alkaloid nicotine from *Nicotiana* species is another secondary compound widely used as an insecticide despite its high toxicity to man, and one could make a long list of plant species which have been used as insect repellants in various parts of the world.

It is usually preferable that a pesticide or deterrent should be highly specific with regard to its target organism and negligibly toxic to man. Alternatively, if the compound is present in a plant destined to become human food, it may be sufficient to ensure that it is removed or destroyed during processing or food preparation. If a secondary compound meeting these criteria is identified in a plant, it may be possible to take advantage of its presence in more than one way. It may, for example, be possible to increase the plant's resistance to a herbivore or pathogen by developing crop varieties containing relatively high concentrations of the appropriate secondary compound. It may also be possible to isolate the secondary compound for use as an insecticide or fungicide in its own right or by reference to the chemistry of the natural product to design synthetic variants with improved characteristics.

THE DETERMINATION OF PHYSIOLOGICAL ACTIVITY IN INSECTS

Secondary compounds may affect insects in a great many ways. They can act as attractants or repellants, they can stimulate or inhibit feeding, they can provide the insect with an essential ingredient of its diet or they can prove lethal by disrupting a major metabolic cycle on interfering in some other way with the insect's life processes.

Most available information on the effects of secondary compounds on insects is concerned with the concentrations at which particular compounds will kill particular insects when included in their diets. Of equal or even greater importance in the context of pest control is information concerning the concentrations at which particular compounds will deter particular species from feeding. It must be clearly understood that the toxicity of a secondary compound and its properties as an antifeedant may be totally unrelated. In evaluating secondary compounds as potential pest control agents, it is therefore desirable to evaluate them both as potential toxins and as potential antifeedants. The toxicities of secondary compounds to insects are relatively easy to establish by means of standard feeding experiments. The evaluation of their activity as antifeedants is more difficult. Using electrophysiological techniques (Blaney & Simmonds 1983), however, it is now possible to monitor an insect's response, either to crude plant extracts or to purified secondary compounds. The method, which requires the use of small volumes of plant extracts or purified component in solution, can rapidly establish whether a particular plant extract or compound stimulates or inhibits feeding in a particular insect. The potential of these methods for the identification of new, naturally occurring insect antifeedants is obvious. Equally important, however, is the insight that they can give as to the ways in which an insect's response to a particular component in a plant extract can be modified by the presence of other components. One insect may respond, positively or negatively, to a given concentration of a single secondary compound whereas the behaviour of a second insect may be governed by the complete chemical profile of the plant.

THE POTENTIAL OF POLYHYDROXY ALKALOIDS (NITROGEN SUGARS) AS AGENTS FOR PLANT PROTECTION

The discovery, isolation and biological activity of a novel group of secondary compounds - polyhydroxy derivatives of octahydroindolizine, pyrrolidine and piperidine - have been reviewed recently (Fellows et al. 1986). These include an isomer of 2-hydroxymethyl-3,4,5-trihydroxypiperidine which can also be described as 1,5-dideoxy-1,5-imino-D-mannitol or deoxymannojirimycin (Fig. 1) which was isolated from the legume Lonchocarpus sericeus (Fellows et al. 1979), the corresponding analogue of glucose originally called moranoline when first isolated from a mulberry species (Morus nigra) by Yagi et al. (1976) but now generally called deoxynojirimycin (Fig. 2) as it is also formed by reduction of bacterial nojirimycin (Schmidt et al. 1979, Murao & Miyata 1980), and fagomine (Fig. 3), a compound related structurally to the first two molecules but lacking an hydroxyl group at C5 (C2 if considered as a sugar), which was isolated (Koyama & Sakamura 1974) from buckwheat (Fagopyrum esculentum). All three may be regarded as analogues of pyranose sugars in which the ring oxygen has been replaced by nitrogen. The mannose analogue was found to inhibit α-mannosidase from various sources and mammalian α-L-fucosidase but not α- or β-glucosidase. The glucose analogue in contrast inhibited both α- and β-glucosidases from various sources including fungal trehalase, while fagomine showed no inhibitory action towards any of the carbohydrase enzymes tested, indicating that the presence of an hydroxyl group in the C5 position is an important factor in determining carbohydrase inhibition.

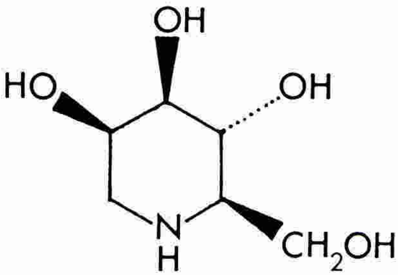

Figure 1. Deoxymannojirimycin

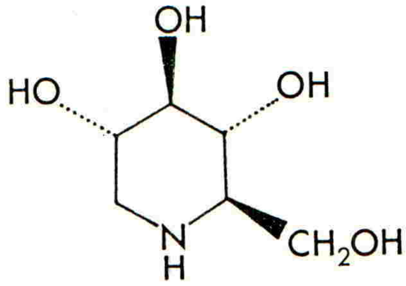

Figure 2. Deoxynojirimycin

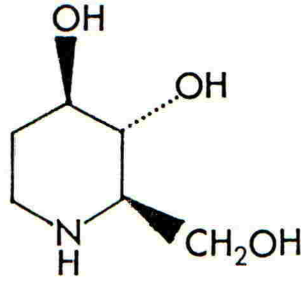

Figure 3. Fagomine

The polyhydroxy pyrrolidines, 2,5-dihydroxymethyl-3,4-dihydroxypyrrolidine (DMDP, Fig. 4), isolated from Derris elliptica (Welter et al. 1976), 2-hydroxy-3,4-dihydroxypyrrolidine (Fig. 5), from Angylocalyx boutiqueanus (Nash et al. 1985a, Fleet et al. 1985) and (2R,3S)-2-hydroxymethyl-3-hydroxypyrrolidine (Fig. 6), isolated from Castanospermum australe (Nash et al. 1985b), may be regarded as analogues of furanose sugars and it is of interest that DMDP, an analogue of β-D-fructofuranose, is a potent inhibitor of carbohydrase enzymes including yeast invertase (50% inhibition at 5.25 x 10^{-5} M) and insect trehalase (Evans et al. 1985a). The compound also proved lethal to the larvae of the bruchid beetle Callosobruchus maculatus when 0.03% was included in the diet (Evans et al. 1985b). DMDP also reduced feeding in the 5th instar nymphs of the acridids Schistocerca gregaria and Locusta migratoria when included in sucrose discs at levels as low as 0.001% (Blaney et al. 1984). The compound from A. boutiqueanus (Fig. 5), which can be described as 1,4-dideoxy-1,4-imino-D-arabinitol, was found to be a more potent inhibitor of yeast α-glucosidase that either deoxynojirimycin (Fig. 2) or DMDP (Fig. 4). The compound from Castanospermum australe (Fig. 6), which lacks an hydroxyl group in the 4 position, was a very weak inhibitor of some glucosidases, but it did deter S. gregaria from feeding when included in sucrose discs at 0.1%.

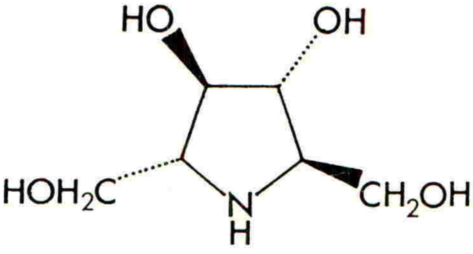

Figure 4. DMDP

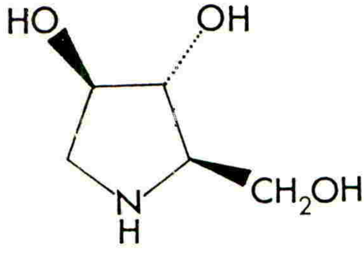

Figure 5.

Swainsonine (Fig. 7) is the polyhydroxy indolizidine alkaloid responsible, in part at least, for the toxicity to grazing animals of Swainsona species in Australia (Colegate et al. 1985) and loco weeds (Austragalus and Oxytropis spp.) in America (Molyneux et al. 1985) and castanospermine (Fig. 8), a closely related compound which was isolated (Hohenschutz et al.

1980) from seeds of the black bean (Castanospermum australe), an Australian leguminous tree which is reported to be toxic to man and grazing animals.

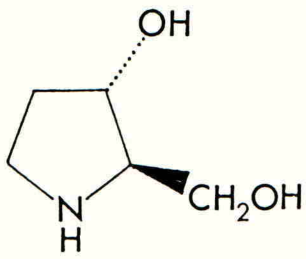

Figure 6.

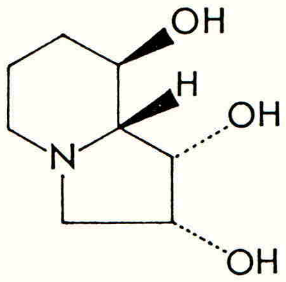

Figure 7. Swainsonine

Swainsonine is an inhibitor of α-mannosidase and induces in animals a lysosomal storage disease which resembles a genetic disorder characterised by a lack of α-mannosidase (Cenci di Bello et al. 1985). Castanospermine in contrast is relatively inactive against α-mannosidase but is a powerful inhibitor of the α-D-glucosidase and β-D-glucosidase enzymes in the alimentary tract of the bruchid beetle C. maculatus and of the β-D-glucosidase but not the α-D-glucosidase present in the alimentary tract of the flour weevil Tribolium confusum. The compound was, however, strongly inhibitory towards the β-D-galactosidase activity of the alimentary tract of T. confusum. Castanospermine is also lethal to C. maculatus larvae at concentrations of 0.03% and 0.1% respectively. The locust L. migratoria (but not S. gregaria) was inhibited from feeding when 0.02% of castanospermine was included in sucrose discs.

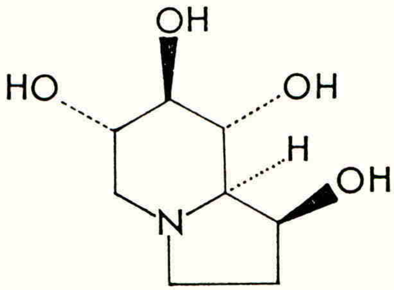

Figure 8. Castanospermine

CONCLUSIONS

Plants synthesise and accumulate many secondary compounds that are physiologically active in other organisms. There is now overwhelming evidence that certain of these compounds contribute to the anti-predator defences of the plants in which they are found.

Recent studies of the biological activities of a small number of polyhydroxy alkaloids clearly indicates that individual compounds may be highly specific with regard to the organisms that they affect and/or the enzyme systems with which they interfere.

It is suggested that a study of such compounds and the identification of those with specific activity against specific insects or pathogens and enzymes could provide a valuable insight into the structural requirements of molecules capable of disrupting metabolic pathways or enzyme systems which are present in specific pest organisms but absent from the host plant and man.

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IMPROVEMENTS IN THE EFFICACY OF MICROBIAL CONTROL AGENTS

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ABSTRACT

Microbial control agents have successfully been used for a number of years for the control of crop pests. Their apparent safety coupled with appropriate efficacy makes them attractive to an environmentally conscious society. Unit activity in terms of production costs, persistence and delivery systems are factors which have worked against more widespread acceptance. Recent advanced technology have broadened the opportunity for improving microbes to resolve the limitations. Using transfer techniques insecticidal toxin producing genes have been transferred to bacteria capable of colonizing agriculturally important crops.

INTRODUCTION

For many years microbial agents have been evaluated for novel bioactive materials. The concept of using natural biological control systems in agriculture has appealed to many research scientists. It is perhaps surprising that to date only limited success has been achieved in translating the concept into the reality of products.

Interestingly, the biological control of insects has resulted in relative success. Bassi isolated the fungus Beauveria from a diseased silkworm (Bombyx-mori) in the middle of the last century (Bassi, 1853). Pasteur had earlier recognized the toxic effects of the bacterium Bacillus thuringiensis. It may well be that these observations set the direction for the earliest efforts into microbial control and which are still reflected today.

Current microbial insecticides

Examples of microbial insect control used in practical plant protection are well documented. They include representatives from bacteria, fungi, virus, protozoa and nematodes. A large number of bacteria are reported as entomopathogens, but only a few are well studied. Of these the use of B. thuringiensis against lepidopterous insects is the most successful. Other bacteria having economic impact are B. popilliae controlling Japanese beetle (Popillia japonica), B. moritai effective against houseflies (Musca domestica), and B. sphaericus for control of mosquitoes. Also active against mosquitoes is the strain B. thuringiensis sp. israelensis.

Examples derived from fungi are restricted. The limited knowledge about the mode of pathogenesis of entomopathogenic fungi and their sensitivity to environmental factors appears to have restricted our progress. Beauveria bassiana is used to control the Colorado beetle (Leptinotarsa decemlineata) in the USSR and for control of the European corn borer (Ostrinia nubilalis) in China. Verticillium lecanii is a recent introduction for the control of aphids and other pests in glass house environments. Metarhizium anisopliae is used for the control of spittle bugs (Mahanarva posticada) in Brazil.

The Baculouviridae family of viruses is recognized as having insecticidal properties. With a restricted host range it has been argued that they will be safer than other viral insecticides (WHO, 1973). A number of examples have been considered for registration in the USA, including the nuclear polyhedrosis viruses which infect cotton bollworm (Heliothis zea) and the European pine saw fly (Neodiprion sertifer). Also in the Baculovirus group is the granulosis virus infecting codling moth (Cydia pomonella). Protozoa and nematodes are also represented in the insect control arena. Nosema locustae infects grass hoppers (Melanoplus ssp.) whilst the Neoplectana carpocapse and N. glaseri inject a number of insects.

STRATEGIES FOR MICROBIAL CONTROL

Comparison with chemicals

Chemicals have an established role in the cost effective control of insect pests. Unfortunately they are also perceived as having significant negative impacts on the environment. The move towards Integrated Pest Management has drawn attention to the non specific action of some chemical groups. Microbials with selective activity give the potential for good control of a specific target, leaving the beneficials unaffected.

Microbials until more recently had a positive environmental image. The long term and safe use of B. thuringiensis has helped to build that image. The prospect of introducing genetically modified microbes into field trials has brought attention to potential hazards including toxicological issues. It appears likely that all microbials will be faced with a similar range of registration issues that chemicals have faced. In terms of production, formulation, packaging and application, chemicals have a well researched and effective track record. Microbes on the other hand, have received modest attention in these fields and yet are faced with their own unique problems.

Evolving techniques in molecular genetics have opened new horizons for the potential manipulations of microbes. Changing technology has also refocused our attention on the criteria to be used in evaluating the opportunities. Through the modern methods of gene technology entomopathogenic organisms can be manipulated to improve production, increase efficacy, field persistence, and activity spectrum. Toxic genes from insect pathogens can also be engineered into alternate hosts which are more amenable to field usage. The engineered organism may be killed after it produces the toxin and becomes a carrier that protects the toxin from environmental degradation, or plant microflora may be utilized as delivery vectors for a pesticidal gene. In the long term this latter approach holds the greatest potential for the future of microbial pesticides. Systems can be envisaged where root colonizers, phylloplane colonizers and perhaps even endophytics can serve as efficient carriers of a pesticidal gene.

DEVELOPMENT OF A GENETICALLY ENGINEERED MICROBIAL PESTICIDE

Selection of toxin and microbes

To illustrate the use of genetic engineering the approach has been utilized within Monsanto for the transfer of B. thuringiensis (B. t.) toxicity to a root colonizing microbe is presented. The origins of B. t. and the activity associated with the presence proteinaceous parasporal inclusion bodies are well known (Luthy et al. 1981). The range of B.t. subspecies in which differing specificities of toxicity can be found is increasing well documented (Krieg & Langenbruch 1981). Example: B.t. subsp. kurstaki is active on lepidoptera whereas subsp. israelensis is active on diptera. More recently subspecies active on coleoptera have been recognized (Krieg, et al. 1983, Herrnstadt et al. 1986). These, featured together with safe use over many years, have made B.t. a most attractive target for researchers and it is increasingly used in genetic manipulation for toxin delivery.

As part of the Monsanto biotechnology program, a project was established whereby the B. thuringiensis delta-endotoxin would be delivered through a living bacterial species found to be associated with a target crop. In Missouri-grown corn, microbes are found to colonize the roots at a density of 10^7 colony forming units per gram of fresh roots. Pseudomonas fluorescens was identified as one of the most significant components and two isolates were selected for our prototype toxin delivery system. These isolates differed from each other in morphology and growth characteristics, but both possessed all the desirable characteristics for a receipt of a pesticidal gene: (a) lack of pathogenicity to humans, plants and non-target insects; (b) high degree of association with plant roots; (c) sensitivity to clinical antibiotics and sterilants; (d) limited potential for genetic exchange; and (e) limited environmental persistence. These isolates had not previously been worked on genetically. As a first step into making these strains useful for genetic manipulations, a selection for spontaneous mutants of the wild-type strains which conferred resistance to rifampicin (rif-r) and nalidixic acid (nal-r) was carried out. This had no effect on colonization or any other property of the strains.

Introduction of B. thuringiensis delta-endotoxin gene into soil Pseudomonas

Through careful selection of appropriate plasmids it was possible to introduce the plasmid contianing the B.thuringiensis delta-endotoxin gene into the two selected root colonizers by three methods: (a) triparental matings, (b) direct transposition and (c) homologous recombinations. Triparental mating is achieved by mixing three strains of bacteria, followed by concentration and incubation on a non-selective medium for a period of time suitable for genetic exchange to occur. In our case the three bacteria were the recepient pseudomonas strain, an E. coli containing a plasmid carrying the B.thuringiensis tox gene, and the third, another E. coli carrying a plasmid with transfer functions which can mobilize the plasmid containing the tox gene (Watrud et al. 1985). The desired product of the matings (i.e., the two strains of Pseudomonas fluorescens harboring the appropriate tox gene) were selected from the rif-r and kan-r techniques.

This bacterial conjugation technique provided an expedient means for introducing a plasmid containing the tox gene into the corn root colonizing Pseudomonas strains for expression in the laboratory. The technique is counterbalanced by certain features which make it less suitable for environmental release. In the absence of antibiotic selection, this plasmid is somewhat unstable, particularly in one of the strains. Such instability is undesirable for field testing and eventual wide-spread commercial use. In addition, these plasmids could potentially be mobilized by conjugative plasmids likely to be present in the environment. To overcome problems of plasmid instability and increase containment, procedures were developed for insertion of the tox gene into the chromosome of the root colonizing bacteria.

Transposon mediated chromosomal integration

The two methods employed for chromosomal insertion, direct transposition and homolgous recombinations, utilized the transposable element Tn5. Tn5 is well known for its relatively high efficiency and low specificity of insertion in many different microorganisms. In addition, Tn5 contains auxiliary genes coding for kanamycin resistance (kan-r) which facilitates selection and can carry genes coding for other functions without interfering with the transposition per se (Obukowicz et al. 1986a). The tox gene was cloned into the central region of the Tn5 transposon where earlier gene mapping had shown that transposition would not be impaired. The suicide plasmid pGS9 was used as the delivery vehicle. This plasmid was engineered for Tn5 insertion mutagenesis, encodes for broad range conjunctive transfer functions, is maintained in E. coli but does not function in non enteric bacteria such as root colonizing Pseudomonas. Overnight mating of E. coli containing the engineered pGS9 plasmid with our Pseudomonas strains resulted in transposition of the Tn5-tox construct into the chromosome of the root colonizing bacteria. Transposition events into the chromosome were selected by maintenance of antibiotic resistance genes carries by the Tn5 element. Quantitative immunological analysis and insect toxicity studies indicated that the insecticidal protein toxin constituted approximately one percent of the total protein.

Elimination of the transposon functions of Tn5 tox constructs

In principle the Tn5 tox construct inserted into the chromosome has retained the ability to transpose to other sites in the chromosome or to an incoming plasmid. Even though our root colonizers do not accept or maintain plasmids of the most common broad host range groups, scenarios can be invisaged where other less common plasmids present in the environment may spread the tox gene to other bacterial species. In order to minimize the potential of horizontal gene transfers to other bacteria two approaches were taken to eliminate the ability of the Tn5 to synthesize the protein needed for transposition (transposase). The first utilized a portion of Tn5 without transposing the entire transposon (Obukowicz et al. 1986b). The second utilized homologous recombinations between a Tn5-tox construct with substantial deletions in the transposase function and a Tn5 previously inserted into the chromosome (Obukowicz et al. 1986c). Both approaches resulted in successful expression of the B. thuringiensis kurstaki delta-endotoxin protein.

Environmental considerations in the design of a living pesticide

Starting from the belief that it is possible to engineer bacteria which would serve as a living, a specific pesticide, the second step was to ensure that no adverse ecological consequences could be foreseen when used on field crops. The initial prototypes had the tox gene inserted within a plasmid which was recognized as a risk from the potential of bacterial conjugation into other organisms. Following the gene insertion through the Tn5 the potential to transpose to a plasmid which may move into this strain did exist. Attempts were made to theoretically determine the frequency at which such transfers could take place. This theoretical approach gave rise to the view that the probability was indeed exceedingly low. Nonetheless, the elimination of the transposase recombination reduced the possibility of transposition to such a low level that it was considered non-detectable in the laboratory.

CONCLUSION

The work described points the way to demonstrating that genetic exchange can give rise to organisms capable of producing toxin at levels suitable to achieve the required quantity to kill the target organism. All of the work described above is restricted to laboratory activities. The important next step is to demonstrate that the colonizer concept will translate into field terms. Small scale field trials in which the survival and colonization ability of the transformed Pseudomonas are studied. At the same time, it is important to determine whether the restricted colonization can be confirmed by monitoring bacterial populations both on other plant parts and in the environment.

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BIOTECHNOLOGY: REGULATING FOR THE UNKNOWN

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ABSTRACT

Biotechnology is perceived by the public as fascinating and at the same time frightening. However, public acceptance of risk can be influenced by increasing public confidence in risk management. Examples are presented how risk perception influences regulatory decisions. Guidelines for regulations for release of genetically modified organisms into the environment are proposed which include measures for risk management.

THE KNOWN AND THE UNKNOWN

The borderline between the known and the unknown is never clearly defined. For the scientist the unknown represents a challenge; it has the fascination of the ground never touched which led our ancestors to put to sea in order to discover new continents. At the same time the unknown is full of dangers, frightening monsters and potentially destructive powers. This has always been the case: The man who drew a map of the world several hundred years ago wrote in areas of terra incognita in bold letters: Here are the dragons.

Biotechnology is at the frontier of science. It reaches from the known into the unknown. It, therefore, has the two faces, the fascinating and the frightening.

At a meeting at the University of California in Los Angeles a petition to the Environmental Protection Agency in Washington DC was circulated which said: "Over the last decade we have seen the techniques of recombinant DNA bring about previously unimaginable advances in our understanding, both of fundamental processes of life and of many socially important biological problems. It is clear that the tools are becoming available for harnessing that understanding in biotechnological applications of profound social benefit, in fields such as human health, crop improvement and the fight against pests, parasites and pathogens. For example, it is now possible to envisage the gradual replacement of indiscriminate and ecologically damaging chemical pesticides by crop plants which are inherently resistant to pests, or by biological control agents that are highly specific and ecologically acceptable". Here is the fascination of the unknown and the optimism that, once we are able to cross the line, exciting new opportunities suddenly open up.

On the other hand an opponent to the field tests of the University of California in Berkeley which are planned in northern California said at a public meeting of the Tulelake City Council: "When you are dealing with a crazy cell, boy, you've got problems! Now molecular biologists have found a way to alter all life, by combining genes into new substances called recombinant DNA, the most dangerous biological technology in existence to-day, perhaps more so than the atom bomb. These are the most awesome, dangerous, uncontrollable forms of life, cut and fashioned to a mad scientist's fancy".

There we have two widely different perceptions of one and the same thing! And the regulator or the legislator, the civil servant whose task it is to defend the public interest is faced with a difficult job.

A CASE HISTORY

There have been a number of plans for deliberate release of genetically modified micro-organisms or plants from companies such as Advanced Genetic Sciences Inc., Monsanto, Calgene, Biologics Corp., Agracetus, Arco Plant Cell Research Institute, University of California and Ciba-Geigy.

Let us go through one particular case history: In 1983 Dr. Steven Lindow, Associate Professor of Plant Pathology at the University of California in Berkeley, submitted an experiment to the NIH recombinant DNA Advisory Committee to use two genetically engineered bacterial strains in a small field test for prevention of frost damage. The application was later withdrawn and resubmitted in March 1986 to the Environmental Protection Agency (EPA). It was intended to apply the bacteria to potato seeds and additionally to spray the bacteria on plants soon after they emerge from the soil (i.e. one month after planting) on two 1 acre potato fields on an Experimental Station of the University near Tulelake, Cal. In addition to checking the degree of frost protection the experimental design also included the collection of data on dissemination and survival of the bacteria in the environment, i.e. monitoring the bacteria population on the plants, in the soil and in, or on bees and other insects associated with the treated plants. These plans, the purpose of the test and the potential benefit were explained by Prof. Lindow and an EPA biologist in April 1986 during a specially arranged meeting to the farmers of the area, for whom frost damage is a very real problem.

However, right from the beginning the Foundation on Economic Trends, in particular Jeremy Rifkin, opposed the tests on the basis of procedural deficiencies (e.g. the lack of a formal environmental impact assessment or the absence of adequate liability insurance coverage) although in 1984 he had publicly acknowledged (Chem. and Eng. News 1986) that Dr. Lindow's experiment poses almost no risk to the environment or human health. In his fight to prevent the initiation of the experiment Rifkin was supported by a group called "Concerned Citizens of Tulelake". Since the University of California had announced previously that it would not proceed with the test in the face of official opposition to it, the field tests have now been delayed until next spring.

LESSONS TO BE LEARNED

What do we learn from this story ? "Public acceptance of any risk is more dependent on public confidence of risk management than on the quantitative estimates or risk consequences, probabilities and magnitudes" says Chancey Starr (Starr 1985) in a recent article in "Risk Analysis". In the same article he gives an interesting example of the three options for protecting the public from risk: The political, the technical and the managerial solution to risk management. He exemplifies this with the tiger in the zoo. There is a certain risk that he may escape and kill a nearby resident. The political solution is to order the elimination of all tigers from zoos. The technical solution would be to declaw and defang the tiger. A managerial solution is to cage the tiger securely and provide alert zookeepers to keep the access gates closed.

Applied to our case it is clear that Jeremy Rifkin is aiming at the political solution: Genetic engineering must be eliminated absolutely from the face of the earth (Rifkin 1985). The technical solution is not so simple: You cannot prove safety unless you do the experiment and prove that it does no harm. It is the same situation as the one when a chemist was told by his boss not to synthesize any toxic substances any longer. "How can I find out whether the new substances I want to make are toxic or not if I don't synthesize them ?" the chemist replied. In the environmental release case the risk of harm to the environment can be estimated on the basis of results from contained experiments, but only the release itself and the careful monitoring of the experiment can give reliable indications about the real risks.

Finally there is the managerial solution; it is my impression that not enough attention has been paid to this aspect. In the public debates no answer was given to the "what if" question. What would be the corrective measures if a released organism or plant would behave in an unexpected manner.

The steady diminuendo of the debate on recombinant DNA research which started with the big bang of the moratorium of Prof. Paul Berg in 1974/75 was possible precisely, because politicians and the public were assured that at the beginning genes would be spliced only under strict containment rules. Since many of the early fears proved in practice to be unfounded, guidelines could be continuously relaxed without opposition from the public and the media. The prominent exposition of risk management in the early stage had a decisive influence. There is clearly an educational task to be done. The critics of biotechnology very effectively word their messages for the man on the street. The biotechnologists have not been able to communicate equally well, despite considerable efforts by such organisations as the University of California or Monsanto. People need not understand what biotechnology is all about, but they do need confidence that any potential risk is properly taken into account and managed. Only then the perception of the risks will fall in line with the facts. In this context it is perhaps significant that none of the planned experiments for deliberate release of genetically modified organisms in the US were held up, because of factual deficiencies but rather by actual or presumed procedural or legal deficiencies.

THE UK-CASE

In the United Kingdom the release of a genetically modified Baculovirus which infects the caterpillar of a moth that causes severe damage to lodgpole pine trees in Scotland has generated some public discussion (Nature 1986, New Scientist 1986). The experiment was carefully planned by Dr. David Bishop of the Natural Environmental Research Council's Institute of Virology in Oxford and was cleared by the Health and Safety Commission's Advisory Committee on Genetic Manipulation (ACGM), the Department of the Environment, and approved in principle by the Ministry of Agriculture, Fisheries and Food and supported by the Nature Conservancy Council. Judged by the relatively low intensity of the public reaction to Dr. Bishop's experiment it appears that the confidence of the general public in risk management, particularly also in the decisions of the various committee's of the ministries concerned is rather high, although some environmentalists felt that they were not consulted early enough and intensively enough. However, in this climate the intention of the ACGM to proceed by building up "case law" concerning the wisdom of deliberately releasing engineered microbes is a very sensitive approach indeed and contrasts favourably with the highly emotional and non-scientific early reactions in the USA.

Recent experiences of our own organisation, however, demonstrate that even in the US permissions can be obtained smoothly if through proper information, particularly on risk management, the publics' and the regulators' concerns are anticipated. In the Ciba-Geigy submission which was recently approved measures were described to prevent uncontrolled spreading of the tobacco plants which were made resistant to the herbicide Atrazine. All the plants will be destroyed at the end of the experiment and the buds on all 7700 plants will be removed early in order to keep them from pollinating.

GUIDELINES FOR REGULATION

Facing this situation what kind of guidelines should the regulators follow when taking decisions related to biotechnology ? It is a rare event when representatives from five different industrial associations get together and, fully aware of the trends which we have discussed so far, decide to do something and then actually produce something: a short report on "Safety and Regulation in Biotechnology". The report was produced by the European Committee on Regulatory Aspects of Biotechnology (hence the report is called the ECRAB Paper) at the request of the Commission of the European Community. The report was formulated by a small group of scientists from the UK, Germany and Switzerland and approved by all five associations, namely the Association of Microbial Food Enzyme Producers (AMFEP), the European Council of Chemical Manufacturers' Federations (CEFIC), the Confederation of the Food and Drink Industries of the EEC (CIAA), the European Federation of Pharmaceutical Industries' Associations (EFPIA) and the International Group of National Associations of Agrochemical Manufacturers (GIFAP). The involvement of all these industries demonstrates the broad field of applications for biotechnology.

The paper first of all states that it is impossible to cover all aspects of modern biotechnology in one single set of guidelines and rules. Applications could conceivebly range from human gene manipulation to antibiotics or vaccine production or waste disposal. Only Rifkin's political solution would apply to all applications: abolish biotechnology totally and altogether.

Then the ECRAB paper points out that one has to distinguish three different aspects which are the subjects of different types of regulations:

a) The approval for sale and distribution of products (herbicides, pesticides, pharmaceuticals, diagnostics, etc.) which are produced by using a biotechnological production process. This aspect can be dealt with to a very large extent, if not totally, by existing rules and regulations. After all insulin is insulin whether extracted from pancreatic cells or produced by *Escherichia coli*, provided it is carefully purified and analytically characterised.

b) The safety of the biotechnological production processes which use living organisms or cells, both for the people who handle these organisms and for the environment. The technical means to protect the workers and the public are well known and installed in all fermentation plants and vaccine production units, where even highly pathogenic organisms can be handled safely. The excellent safety record of this industry demonstrates the effectiveness of the risk management. In addition the Organisation for Economic Cooperation and Development (OECD) has recently published recombinant DNA Safety Considerations which describe in detail the Good Industrial Large Scale Practice (GILSP) rules and recommendations.

c) The deliberate release of genetically modified live organisms into the environment is, however, a proposition for which no close precedent exists. Of course, there is a long history of safe release of products of conventional plant and animal breeding and large numbers of micro-organisms have been commercially released in order to achieve a desirable effect. These micro-organisms have certainly undergone some mutations and the selected strains are certainly different from the "wild types". Nevertheless the possibilities for changes are far greater with the modern techniques of biotechnology. We are therefore clearly entering the realm of the unknown. Risk assessment and, above all, risk management in the area of release of live organisms therefore becomes of prime importance.

Risk management requirements vary during the life-time of a project from initiation in the laboratory until the moment when release is actually taking place. In addition, risk management will be very different if we are dealing with rapidly proliferating organisms such as bacteria, viruses or fungi, where in a single experiment thousands or millions of individuals are used, or whether you use insects where a few hundred might be used for an experiment, or a plant where 50 to 100 plants might be sufficient, or farm animals where a few individuals are used at a given time.

It is also clear that as long as risks are totally undefined risk management must be very strict. We recall the early time of the Berg moratorium of recombinant DNA experiments. As we do experiments under strictly contained laboratory conditions we learn more about the organisms' behaviour and some of the original potential risks become either defined or irrelevant. In small scale, closely monitored, semi-contained experiments (e.g. in glass houses) we can again study the behaviour of our organisms under conditions already closer to real life, i.e. release conditions, and again eliminate or more precisely estimate the remaining risks. When it finally comes to the release experiment we not only know most of the remaining risks, we can also quite precisely define what measures must be taken in order to stop the experiment and kill or contain the organisms in case anything unexpected happens.

This is exactly how the risk assessment proposal reads: It proposes five steps for the risk assessment, 1) at project initiation, 2) at the end of the contained laboratory experiments, 3) at the end of closely monitored, non-contained small scale experiments, 4) at the end of controlled field tests, 5) during commercial applications.

Based on previous experience and general knowledge the containment level for the step 2 is defined at the initiation step. For the other steps the information requirements which are necessary for the initiation of the next steps are always the same: a) Assessment of the capability of the organism to survive / to multiply / to spread, b) Risk and type of exposure of humans, c) Risk and type of exposure of animals (insects, wild animals, farm animals) and of various crop plants, d) Interactions with other relevant components of the ecosystem, e) Contingency measures.

This information must give rise to the definition and implementation of risk management measures and plans, namely: Experimental design and monitoring systems must be adequate, precautionary and safety measures for workers must be defined and instructions issued, proper safety measures and monitoring systems must be in place, potential consequences must be evaluated, monitoring systems put into place and countermeasures planned, and finally installations, instructions and materials must be ready to terminate the experiment at once if unforseen events should occur. These are typical preparations for effective risk management.

The proposal also fully recognises the importance of the confidence which the general public must have that all these risk management rules are in fact followed. The industry proposal, therefore, suggests that the data for these risk assessments and the plans for risk management are deposited officially in order that the authorities are in a position to check their validity and effectiveness.

It is clear that industry cannot agree to make these data publicly available to everybody for obvious competitive reasons. But we feel that the authorities should be advised in their evaluations by expert committees in which independent competent representatives from the civil service and academia, environmentalists, etc. and industry should be represented.

The industry proposal is very much in line with the guidelines for risk assessment and for notification of proposals for planned release of genetically manipulated organisms for agricultural and environmental purposes issued earlier this year by the UK Advisory Committee on Genetic Manipulation.

CONCLUSIONS

We cannot eliminate the unknown, nor can we formulate rules and laws which cover every eventuality. This would in fact totally stifle research or drive some of the activities under ground. What we need is take away from the unknown the anxieties about the potential catastrophic consequences which might or might not occur. We can only do that if we can demonstrate that experiments cannot turn irreversibly bad if we pay proper attention to risk management. But this is not enough, we have to convince the general public that we are very serious about this approach and that we are willing to explain every detail about it in a language which is understood by the man on the street. This I think is a task for all of us.

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SESSION 6

INFORMATION EXCHANGE IN FUTURE CROP PROTECTION

CHAIRMAN MR G. H. JACKSON

SESSION ORGANISER DR D. J. ROYLE

INVITED PAPERS 6-1 to 6-4

INFORMATION EXCHANGE IN FUTURE CROP PROTECTION - A GOVERNMENT ADVISORY SERVICE VIEW

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ABSTRACT

The agricultural advisory service in England and Wales is evolving from a free service to one in which charges will be levied for a range of activities, including advice. The sources of information for both advisers and farmers are reviewed. Examples are given of ways in which information transfer has been developed and improved, and some possibilities for the future are examined.

INTRODUCTION

The Agricultural Development and Advisory Service (ADAS) is unusual in being an advisory service for farmers operated directly by central government. Its origins lie in the Agriculture Act 1944, which required Ministers to provide free advice on agricultural matters, and to establish an advisory service to do this. ADAS operates in England and Wales; advice for farmers in Scotland is provided through the three agricultural colleges, an arrangement similar to that which existed in England and Wales before the National Agricultural Advisory Service (predecessor of ADAS) was established.

Although ADAS is part of the Ministry of Agriculture, Fisheries and Food (MAFF) and provides technical support to the implementation of government agricultural policy, the remit for its advisory activity has always been to advise farmers and growers in their own individual best interests.

In farming, as in other businesses, economic considerations can never be ignored, and are usually predominant. Over the last 25 years, economic considerations coupled with the wide-ranging advances in agricultural technology have meant that advice has been largely production-oriented. Farmers' objectives can also include factors such as crop quality and market opportunity, as well as their own interests, abilities and aspirations.

CHARGING FOR ADVICE

Until 1971, all advice and services to farmers provided by ADAS were free. Since 1972, charges have been made for a range of laboratory services. More recently the Government has announced reductions in public expenditure for both R&D and advice, on the basis that the industry as the main beneficiary should make a direct contribution to the costs of these activities.

The first consequence of these changes is that ADAS is now undertaking contract R&D for commercial organisations and for farmers' groups. Also, levy funding for R&D is being established in the horticultural and cereal sectors. The Agriculture Act 1986, which received the Royal Assent in July of this year, empowers Ministers to make reasonable charges for advice. From 1987 there will be charges for much of the advisory work done by ADAS, although free advice will continue to be given on a number of topics, including conservation and protection of the environment.

Charges were introduced in December 1985 for the laboratory diagnosis of crop disorders. This has resulted in fewer samples being received, especially for the confirmation of relatively simple problems. The outcome is a smaller input of crop intelligence from this source and a reduced chance of detecting new problems at an early stage.

SOURCES OF INFORMATION FOR ADAS

As an organisation concerned with transfer of technology, ADAS uses a wide range of sources of information. There is a very large body of publicly-funded R&D carried out by Institutes of the Agricultural and Food Research Council (AFRC), Universities and ADAS. In 1984/85, the expenditure by Agricultural Departments and AFRC on R&D in the crops sector was £67.9M, about one third of the total for agriculture and food. The expenditure specifically related to crop protection was £17.8M. The Priorities Board for R&D in Agriculture and Food has recommended that the proportion of expenditure on crop protection should be maintained, giving priority to environmental and wildlife-related studies and to reducing pesticide use. The total budget is however being reduced by £10M in 1986/87 and £20M in 1987/88. It can be argued that closer integration is needed between the various organisations involved in R&D, and moves are under way to try to achieve this. The possibilities include co-ordinated programmes between ADAS and AFRC institutes, joint projects for both commissioned and contract-funded work, and greater use of ADAS experimental centres for collaborative work. While publicly funded R&D will continue to be the major source of new information (especially on topics such as environmentally desirable crop protection strategies) the transfer of resources to contract-funded projects may generate information on subjects of lower priority, or with some restriction on its general use by ADAS advisers.

Other important sources of information include manufacturers, consultants, trade associations, overseas contacts, and farmers and growers - both through individual feedback and in responses to surveys. Charging for advice is likely to alter the pattern of the direct contacts between ADAS advisers and farmers. There may be less frequent contacts with smaller farmers, but charging will allow more time to be spent with individual farmers who are willing to pay for services tailored to their needs. Similarly, groups of farmers will be able to contract for a wide range of services, included development work in their locality. In all cases the extent and level of contacts will be determined by the needs of the farmer. While information exchanges with sectors of the industry other than farmers may be subject to more formal arrangements under a charging regime, there is no reason why the contacts should not continue. As with farmer contacts, they could become closer and more fruitful where contract arrangements allow a greater input of ADAS resources than has been possible within a free service.

SOURCES OF INFORMATION FOR FARMERS

Farmers and growers have access to information and advice from a number of sources. Table 1 summarises responses from an extensive market research survey undertaken for ADAS in 1985. ADAS undertakes surveys of pesticide usage on various crops, and some of these have included questions on sources of advice; the results from some recent surveys are shown in Table 2.

Surveys of this kind indicate the farmer's perception of his source of advice, but not necessarily the origin of the information. For example, local merchants figure prominently (as suppliers' representatives in Table 1 and commerce in Table 2), because farmers have very frequent contact with them, but much of the information they provide is derived from manufacturers or from ADAS. Other individuals and groups advising farmers make use of ADAS information from personal contacts, promotional events and ADAS publications, which are comprehensive and frequently updated. An example in the crop protection field is the booklet on the use of fungicides and insecticides in cereals (MAFF, 1986b). This means that information from ADAS reaches many more farmers than those in direct advisory contact.

Farmers perceive and value impartiality as a very important characteristic of ADAS advice. While ADAS intends to maintain its impartial stance, the increase in contract work for commercial organisations carries the risk of this becoming less clearly recognised.

TABLE 1

Results of a survey of sources of information and advice used by farmers

Source	% spontaneous and prompted mentions
Supplier's representatives	75
ADAS/Ministry personnel	65
ADAS/Ministry publications	52
Veterinary surgeons	55
Agricultural press	53
Farmers/neighbours	46
National Farmers Union	34
Research stations	22
Milk Marketing Board	18
Advertisements	17
Private agronomists	16
Meat and Livestock Commission	9
Others	13
None	2
Average number of sources mentioned	4.8

Source: Market research for ADAS, 1985 (unpublished)

Data from 999 full-time farmers

ADVISORY METHODS

The methods used by ADAS for disseminating information include direct contact with farmers, both as individuals (on farm or by telephone) and in groups, and promotional events such as farm walks, open days and conferences. Other media used include publications, the farming press, radio and T.V., Viewdata systems, and the Telephone Information Service.

Printed material is still the preferred method for "encyclopedic" information to which the farmer needs to refer from time to time, and which does not need very frequent updating. ADAS policy on publications is now changing towards giving less background information, and a shorter more prescriptive presentation. Our range of publications includes local bulletins, which are issued monthly to most farmers. These contain topical "awareness" information, but the timescale for their production and distribution makes them less suited for immediate intelligence.

TABLE 2

Results of a survey of sources used by farmers and growers for advice on pesticide use

Source of advice	Orchards 1979	Soft Fruit 1980	Hardy Nursery Stock 1981	Vegetables 1981	Protected Crops 1981/82	Bulbs 1982	Arable 1982
	% of Holdings						
Commerce	72	70	46	81	51	62	58
MAFF/ADAS	30	45	56	35	44	67	17
Own knowledge	22	7	42	27	36	48	23
Contractor		4	3			4	4
Other farmers/growers		3	9	6		4	3
Consultant	4			11		1	10
Literature/meetings	13	3	13	4			4
Growers Associations	8	8	1				1
Research Establishments	3		4				
Not known	11	4	1				1
Number of holdings surveyed	203	317	204	301	300	82	495

Source : Pesticide Usage Surveys (MAFF)

Intelligence information on the incidence of pests and diseases is an important input into decision-making on crop protection. Crop intelligence reports are now being issued on a regional basis, with weekly reports through the main part of the growing season. These reports have previously been distributed only to those advising farmers (in both the public and private sectors) but with the introduction of charges they will be available to farmers direct. Less detailed crop intelligence is also included on the Viewdata systems, on the Telephone Information Service, in the farming press, and in radio and T.V. broadcasts.

The number of farmers with access to viewdata systems has increased markedly in recent years. Many organisations now transmit information and advice through this medium and this has led to overlap, duplication and in some cases conflicting advice. It would certainly be less confusing for farmer users if the information and advice frames for each topic could be co-ordinated and integrate the input from all the contributors, or at least from those in the public sector.

TECHNOLOGY AND INFORMATION TRANSFER - TWO EXAMPLES

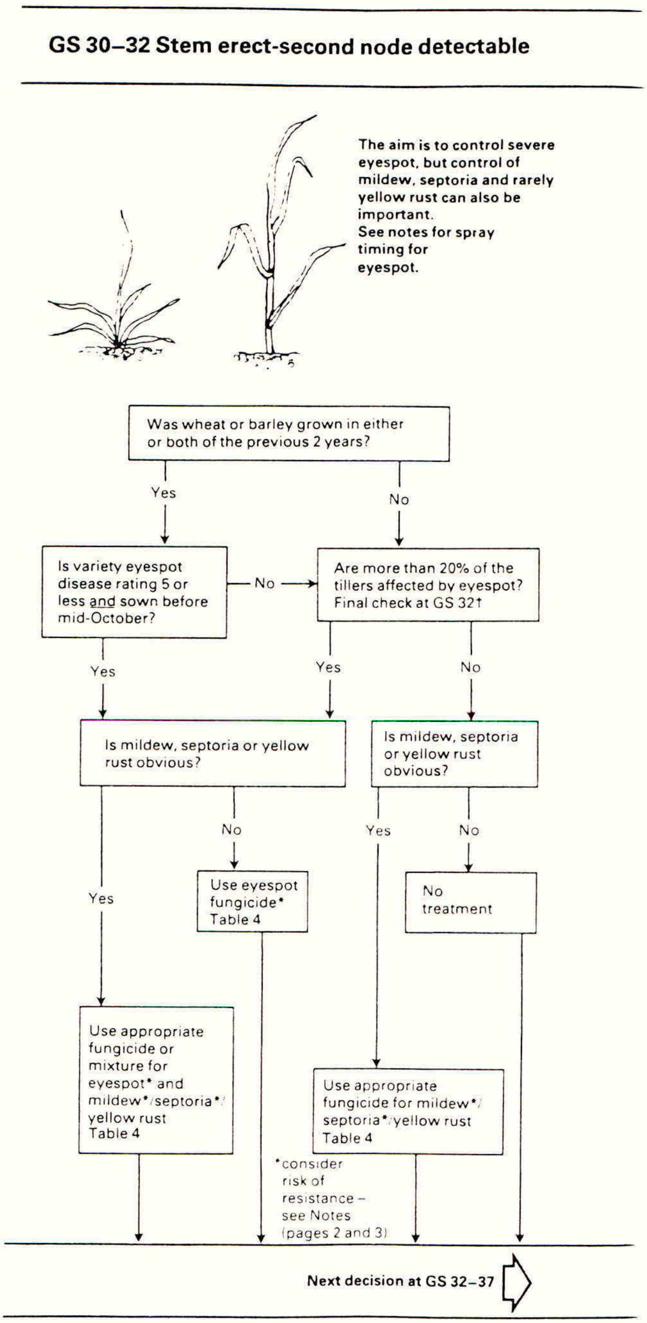
Recent developments in pea moth forecasting and in managed cereal disease control serve to illustrate the ways in which advice on crop protection has been improved and made more specific.

Pea moth (*Cydia nigricana*) is an important pest of both vining and dry harvested peas; accurate timing of sprays for control is essential. Following the development at Rothamsted Experimental Station of pheromone-baited traps, collaborative work with ADAS identified the optimum requirements for siting the traps in crops, and in 1978 a commercial firm marketed the traps as a complete monitoring system. The traps are specific for the pea moth, so there is no problem with identifying the species caught.

Initially, ADAS issued area spray warnings by post. Subsequent collaborative work showed that optimum spray dates could be estimated from temperature records and forecasts. In 1980, the postal warning system was replaced by a telephone service, where a recorded message gives calculated spray dates for a range of thresholds, updated frequently. From 1982, the calculation has been done on the MAFF computer, which also allows the most up-to-date information to be available to ADAS staff all over the country through the computer network. (Blood-Smyth, 1985).

Managed disease control programmes have been developed for all the cereal crops (MAFF, 1985a,b; 1986a). These involve some routine treatments where the risk of severe disease is consistently high, but the main purpose is to guide the farmer in the assessment of disease risk and need for treatment by identifying decision points at key growth stages. These are set out in a series of decision trees. As an example, a portion of the winter wheat programme is shown in Fig.1.

Fig 1. Portion of the ADAS programme for managed disease control in winter wheat



These examples illustrate the way in which advice has been developed from general area-based risk assessment or spray warning to specific field-by-field advice where the farmer inputs the necessary field and crop information and monitoring. At the same time, these developments help to achieve the wider ADAS objectives of minimising unnecessary use of pesticides, minimising the risks of resistance to pesticides, and minimising effects on non-target species and other unwanted effects on the environment.

INFORMATION TECHNOLOGY - DEVELOPMENT OF SYSTEMS FOR THE FUTURE

ADAS has a number of data bases and other information technology (IT) systems in operation. One example is the ADPEST data base on pesticide recommendations, which is being demonstrated at this conference. Another is the disease intelligence data base DISINT, which is being developed in the ADAS Eastern Region. This generates weekly tables of disease incidence, based on reports from ADAS staff and crop consultants. It is used as the basis for the regional intelligence report, but can also be used to give the incidence of diseases for smaller areas, down to an individual adviser's district. Table 3 gives an example table for the incidence of mildew in winter wheat in Norfolk and Suffolk.

TABLE 3

Example output from 'DISINT' disease intelligence database : incidence of mildew in winter wheat in Norfolk and Suffolk

Date (week ending)	% crops in category					Disease index	Total crops seen
	0	1	2	3	4		
09/05/1986	85	15	2	0	0	5	224
16/05/1986	71	27	2	0	0	8	325
23/05/1986	73	18	6	4	0	10	157
30/05/1986	50	43	6	2	0	15	214
06/06/1986	57	29	13	2	0	16	151
13/06/1986	17	19	38	17	8	45	63
	65	26	7	2	0	12	1134

For explanation of mildew categories and disease index, see text

In the input, each crop is scored for each disease on a scale (for which keys are provided) from 0 to 4 (4 being severe infection). The output includes the percentage of crops in each of these five categories, together with a "disease index" which is a weighted percentage (100 = all crops showing severe infection). This gives a quick picture of the build-up of a disease during the season. ADAS advisers are able to input crop records through their remote terminals on the computer network, as well as being able to interrogate the data base for both current and historic information.

As part of its development programme on IT systems, ADAS is currently working on three packages covering dairying, wheat and tomatoes. These are the pilots for a series of comprehensive commodity-based systems. The initial development is for information transfer within ADAS, with all advisers having direct access through the computer network. Decisions have yet to be taken on the way in which these systems will be made available for direct access by farmers and other potential users.

While the potential benefits of such direct access interactive systems are obvious, a very large input of resources is needed for their development, maintenance and updating. There is also the risk of introducing spurious precision in systems which have an inadequate information base. A significant benefit of compiling a comprehensive IT system is that it identifies where the weaknesses exist in the information base, and thereby gives a guide to R&D requirements.

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INFORMATION EXCHANGE IN CROP PROTECTION: A MANUFACTURERS' VIEWPOINT

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ABSTRACT

Information on crop protection and pesticide use is available in many different forms, originates from many diverse sources and is required by many various groups. It is vital that the correct information is available in a usable form at the right time to aid rational use of inputs. Due to the sheer volume and type of information involved computer systems are being used increasingly to aid the exchange of information. ICI has for many years been involved in the use of computers for information exchange and in finding ways to assist growers in achieving their objective of profitably increasing crop yields and quality use of inputs. Some recent developments and future prospects are discussed.

INTRODUCTION

In recent years there have been rapid advances in the technology of information exchange. Information provision is now very much a science of its own. Specialists are employed by large organisations solely to solve their information needs. When information provision is applied to the agricultural community, particular problems are encountered. The agricultural industry is highly developed but its organisational infrastructure is extremely complex. The structure of the information services supporting the industry are also very complex. It is not solely an internal problem as within an office block or between major cities. Ways have to be found of communicating to large numbers of people with diverse interests, in some of the remotest areas of the British Isles.

Although it is difficult to be precise there are well over half a million people professionally concerned with agricultural information. They work in a range of environments - manufacturing, retail, commercial and finance, research institutes, advisory services, educational institutes, media agencies and on farms.

The aim of ICI is to provide good quality information on the recommendations and rational use of its products to support the sales activity. This may be in the form of technical leaflets, handbooks, training or, more recently, by use of computer-aided systems. This paper considers the climate of information exchange from ICI's viewpoint, by first giving a background to our involvement with developing information technology within agriculture. Some major economic aspects of computer-aided information exchange are then discussed. This paper highlights some major areas where ICI is currently involved in the use of computers to aid information exchange, both opposite the general agricultural community as well as internally within the company. To conclude, a few possible scenarios are proposed for the types of systems that might be in operation in the next 5-10 years.

The development of information systems by ICI has been on two fronts. One is directly opposite our customer, where the systems have been largely added value services supporting the use of our products. The other is internal where large volumes of often quite diverse information from around the world has been pulled together and computerised, thereby easing input as well as extraction. Rapid handling of internally generated data is vital if optimum and cost effective use is to be made of it, not least for the updating of systems supporting customer services. The enormous volume of data involved could not be handled without computers.

BACKGROUND TO ICI'S INVOLVEMENT IN INFORMATION TECHNOLOGY

Since the war, ICI has been at the forefront in the use of computer-aided information exchange. This has had the aims of increasing the quantity and quality of crop yields and being able to monitor the use of ICI agrochemicals to ensure that recommendations are being followed, particularly in relation to correct rates and timings of applications.

Over the years ICI has made use of information technology in many ways with its customers. Exchange of information was always important and during the '50's and '60's this was achieved by manual recording systems mainly around the financial area of farm management. This later moved onto the use of mainframe computers for farm planning, an example of which was 'Mascot', a linear program used extensively in the arable areas of the UK to help optimise form resources. Although UK based, this program was used extensively in many parts of the world, ie Pakistan and the United States of America.

During this time the range and use of computers was limited and they tended to be kept in the background. However, during the late '70's their use increased significantly although the exchange of information was mainly achieved by forming special groups with a common interest. One such group became known as the 'Ten Tonne Club'.

In the UK surveys by the 'Ten Tonne Club' were concerned with establishing the cultural practices and inputs of major wheat growers with the objective of identifying the factors for success. Data on proformas from a large number of fields annually were statistically analysed by computer and the findings made available through written reports. Similar work has been established to collect data on the cultural practices in a variety of crops including wheat, maize, potatoes and sunflowers through Western Europe. For instance, Sopra in France established the 'Club de Cent Quintox' which surveyed the practices of a large number of farmers over the main cereal growing areas of France for a number of years. (ICI Sopra 1985). Computerised training programmes such as 'Oats' (Jones 1982) covering crop inputs were developed and also 'Wheatrace', a farm management game looking at rational and cost effective crop inputs. Recent developments have seen the initiation of interactive 'artificial intelligence' systems that can encapsulate human knowledge such as Counsellor (Jones et al. 1984). This can evaluate disease risk and recommend appropriate fungicidal treatment.

For example, The 'Ten Tonne Club' surveys, although successful, had logistic problems. Data collection was on forms, which were posted to a centre then punched onto cards. The computer was used to produce a statistical analysis. The results were collated into a book and the results distributed by hand or at meetings. It was manpower intensive for both the user and provider of the systems. However, although still labour intensive this system was acceptable because at the time it was very much more efficient than previous manual systems and conclusions could still be made available within a few months of the end of the growing season.

As the farmer continued to refine his growing practices there was increased demand for better information. Crop inputs became larger in number and more complex in their application and vast quantities of information about them were being generated by manufacturers and independent organisations. However, it became increasingly evident that it was impossible to disseminate all this information promptly and succinctly to all the right people. Farmers and advisers had to contend with information being published in many forms, text books, journals, research papers, radio and it seemed impossible to keep abreast of the changes taking place. The 1979 CRAIG report (Craig 1979) identified the situation well:-

"Agricultural information, is required in so many different forms to meet different agriculturalists requirements that it is questionable to what extent appropriate mechanisms exist or are being created to present the information in its most useful form and facilitate its transmission through the networks which link agriculturalists in different organisations."

In summary, agrochemical users now have a vast amount of information to absorb if they are always going to make the correct decisions about inputs. We believe it is only through increasing use of more advanced computer systems that this information can be updated and relevant recommendations made available rapidly.

At the same time as we were developing systems for use by our merchant trade and farmers, ICI was improving its own internal information flow. An example is the data recording, analysis and reporting of field trials with development chemicals. As with the 'Ten Tonne' surveys, the traditional way of obtaining trials information was by hand. By the time the information had been recorded, collated, posted and entered onto the central computer, the analysis run and reports written it was invariably too late to meet important policy decision dates and also plan the new field programme. Tremendous pressure was put on personnel to manage the situation and reach conclusions in the best way they could.

Our new field trials information system (FTIS) incorporates the most advanced information technology. Data from trials is collected on a hand held micro-computer and then fed directly into a desk micro-computer situated at the trialist's base. Analysis is thus performed on the spot and the results are immediately available to decision takers. Data is transmitted by telephone link to the central mainframe for storage. Thus, for a particular chemical, results both locally and worldwide are then available to staff of the Division who need to view them. Apart from enforcing standards and a degree of discipline, final trial reports can be generated via a word processing package on the local micro-computer as soon as the trial is completed. The completion date for the summary report of all trials in the series is thereby brought forward. Better and quicker decisions about a trial compound can be made. Additionally, the more rapid availability of the information can form a vital part in maintaining advisory systems.

Although by developing computer systems we have improved our own information handling and flow, interfacing with the agricultural community as a whole is a far more difficult task. The breakthrough has come with Videotex, in particular combined with the use of value added networks (Hutt, 1984). One network, 'Infotrac' was developed and is operated by Istel a company based in Redditch. The concept of the value added network is that the host service pays for the use made of the network and the end-user will then only have to pay local telephone charges.

The use of videotex with its own staff has convinced ICI of its flexibility and ease of use, even for the layman. Videotex is now becoming widely used throughout the world and is best known in the UK as Prestel, the public system. However, over 200 private systems are also in use, primarily in the holiday and motor trade. ICI has its own private systems, which are regularly accessed from home or field base by its field staff and a number of distributors in the UK. The great virtue of videotex is that it has the potential to bring the power of the main frame computer into every home at relatively low cost. Using the ordinary telephone line and, at the lowest level an adapted television set, access can be made to a videotex system. Whilst most systems allow you to look at static pages of text, connection can be made to interactive programs. ICI has extensive experience of running interactive programs through videotex. This brings the power of a mainframe to the end user in a user-friendly form which has led to the rapid expansion of its use.

ECONOMIC ASPECTS OF INFORMATION EXCHANGE

An adequate initial capital budget and continued committment of funds to cover running costs is essential to develop successfully an information exchange system. However, ICI's experience is that with a flexible system which allows most of its business requirements to be met, the benefits and cost savings can easily outweigh the investment. It would not in the end have been practicable to carry on in the more traditional ways. It is now possible to do many things that were impossible previously, including the linking of more advanced advisory systems relating to the use of our products.

Access to all relevant basic information is essential to design an efficient and effective computerised advisory system. Whilst manufacturers have generated a wealth of data concerning their own products and also about more general aspects of crop production, they have also depended very much on the findings of Government sponsored research. Traditionally this information has been freely published in scientific papers and advisory booklets etc. However, the Ministry and associated bodies are currently reviewing their arrangments for providing such information and already have started to charge for some of this service. For example a contract field testing service has been set up. These developments will inevitably increase the cost of providing information. This in turn could cause a change in the economics of information use by the many sectors of the agricultural industry.

Historically the farmer has not had to pay for most of his advice from Government or manufacturer's sources. For many, therefore, spending even a comparatively small sum for information may be hard to accept and justify. This is in contrast to large amounts spent on machinery and fixed equipment, sometimes in excess of real needs. However, in a climate of increasing competitiveness and lower real prices for agricultural products, the need for expert advice is likely to increase rather than decrease.

The overall response by growers and farmers to this new situation will be interesting. Already it is evident that many are prepared to pay more for perceived good advice. For the manufacturer the amount it can afford to spend on developing advisory systems must in the end be related to product sales. These will depend largely on gaining increased market share and customer loyalty through the provision of quality, rational advice and service, particularly when the overall usage of agrochemicals may have peaked, at least in the short term. Whatever the dissemination method information will therefore be constrained in two ways: the ability of the user to access any centrally held information and his perceived use and value of that information in relation to cost. ICI has recognised this as well as the importance to its business of the farmer and adviser easily being able to obtain up-to-date information on which to base decisions. The cost to the end-user will vary depending on the type of equipment installed, but videotex offers a cheap tool to access information from a wide range of sources.

CURRENT AREAS OF COMPUTER-AIDED INFORMATION EXCHANGE WITHIN ICI

Aware of the problems and costs of communication ICI has adopted videotex as one solution. This maximises the potential for providing information to large audiences without the need to set up special expensive communication links.

The introduction of the videotex system 'Agviser' by ICI has demonstrated how we believe that the demand for rapid information exhange is growing. The use of the electronic messaging system alone has been of tremendous benefit to ICI, its customers and the many other users of 'Agviser'. This allows rapid exchange of information about technical product issues, product price changes, reactions in the market and a whole host of other general matters. The information that is required, however, is not the replacement for a product-use manual or last month's market prices; it is the topicality of time-sensitive information that is required of such systems.

The entire evolution of 'Agviser' in its short 3 years of life has been along this theme. As the service has developed the provision and use of the time-sensitive information such as Reuters, Soil Moisture Deficit ratings, Aphid Warning Schemes has increased. Another development has been in the number of interactive programs that the farmer can use to extract some immediate advice, eg a small interactive program produced by Wye College about Septoria disease prediction in wheat.

The recent change in the economic climate together with increasing pressure are causing a change in the type of information required by growers and in the types of information systems required to satisfy this demand. Growers now require very precise information on inputs and are concerned with improving the quality of their crops as well as maintaining high yields.

'N-sure' is a new system that has just been announced by ICI. It is able to make use of many years' data about crop development and meteorological data. In essence the program is a wheat growth stage predictor and is used to establish the best time to apply a nitrogen fertilizer. However, in its current form this system has some of the same drawbacks as previous systems. Users of the system are not generally equipped in such a way that direct access is possible. Instead they have to fill in forms, submit them, have them processed and their results are finally returned. It would seem only sensible that this too should be made available via videotex in order to expand its potential.

In response to farmers' need for quality objective advice, 'Wheat Counsellor', ICI's expert system for wheat disease risk prediction and rational fungicide use recommendation, was designed initially as a planning aid with reactive diagnosis and advice within a cropping season. We have spent the last two years developing and refining Counsellor whilst evaluating it with some of the agricultural merchant trade and farmers. We have learnt much from this exercise and consider the database facilities to be particularly useful. These are used to record information about previous consultations and are recalled when the farmer next uses the system; thus, the length of time occupied by subsequent consultations are reduced. The knowledge held within the system is detailed and in a structured form. This allows the user to extract more explanation of a particular point or to make a more detailed examination of the relevance or importance of a particular line of questioning. The educational value is thus greatly enhanced. The fact that Counsellor is able to support its recommendation with a cost-benefit analysis and offer a complete treatment list of ICI's and other manufacturers products is also considered important. One of the main features that interests farmers is that it should take account of local conditions. It is intended to continue developing Counsellor to emphasise managed disease control and to include other crops.

In Western Europe there have been other developments such as 'Opti-Agro' a micro-based computer program used extensively in France. This is run on a 'clinic' basis where farmers get together at a depot of the local agricultural co-op. The exchange of information takes different forms. Firstly, the farmers use the system to help them formulate their ideas on the use of inputs in wheat growing. Secondly, the clinic approach allows the free flow of information between the farmers and their cooperative's technical specialist, the system acting as the catalyst.

THE FUTURE OF INFORMATION EXCHANGE

In discussing the future we must identify the areas that will most concern both the user of the information and also the generators and suppliers of information. The problems are similar for both parties. Farmers, for instance, will be driven to produce higher quality products, related to what the market demands at the lowest economic cost. The effect of this on the supply industry and agricultural advisers will be that products and advice will need to be tailored to meet the specific objectives of the farmer. This will be achieved by using information systems that enable us to promote and inform about our products. Information exchange should be used in such a way that we can reach the largest relevant audience which is both numerous and widely distributed geographically.

A major barrier to the uptake of computerised information systems to date has been relatively high cost, poor presentation of the information in a number of cases, and difficulty (or perceived difficulty) from the users point of view of accessing, inputting, understanding and using the information provided. The developments that are taking place are designed to overcome these problems. The cost of personal computers and viewdata equipment is reducing and will be judged in relation to the improved quality of the programs and information that is presently being provided.

This is at a time when advice from more conventional sources is less widely available and increasingly more expensive. In addition the successful provision and use of information which has been a major stumbling block in the past, is now receiving a great deal of attention, in particular, in methods for collecting and entering data. For example, the development of automatic 'in-field' weather stations and crop status condition recording systems (Huband, Butler 1984) will allow precise individual grower advice on the need and timing of pesticide applications to be provided. Such developments could be linked with expert systems such as Counsellor. In addition, the inclusion of interactive video disc has provided a new dimension to such systems. Although at the moment the cost is prohibitive to a farmer when used for, identification of diseases or pest infestation levels plus the ability to show moving sequences with sound video disc has an extensive educational and training effect.

Other future possibilities are the use of satellite scanning to give rapid detection of the presence of pest and to activate control advice and even application. Other developments will also simplify using equipment, eg the need for keyboard skills being replaced by touch sensitive screens on which simple choices are presented to the user. Developments in voice recognition will also ease the input and extraction of information.

In order that the range of advice and information is as comprehensive and current as possible, cooperation between the various providers of services is essential. Already there is a high level of agreement between the organisations that offer the information services and those that supply the information. These range from manufacturing companies, through research organisations and government bodies to small private companies offering specialist advice. Each can provide the expertise to improve the overall service as well as making their findings more widely available to relevant interested parties. Some controls have to be imposed to reduce duplication and ensure the integrity and impartiality of the service, but already information from a wide range of organisations as diverse as ADAS, Rothamstead, Reuters, NFU and many others is available on 'Agviser' and this will increase as the services grow and are recognised as major information sources.

ICI will certainly be concentrating its efforts in a number of specific areas. First, in stream-lining the provision of technical information to all interested parties in the agricultural industry. Second by making this information more widely and easily accessible through improved communication methods. Third, by using developments in information technology to train staff, customers and advisers more comprehensively in the use and value of our products.

CONCLUSION

Both the information base and the technology to extract the information are expanding rapidly. It is vital that the agricultural industry continues to capitalize on the opportunities presented by information technology. Many organisations and individuals are already committed to new technology as a way to handle and disseminate the wealth of data that is available. For ICI and other marketing agencies, the costs of providing information will obviously have to be recovered either in product sales or as a separate information service such as 'Agviser'.

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ICI is committed to using information technology as a way to facilitate information exchange in the future, both within the UK and throughout the world.

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INFORMATION EXCHANGE IN FUTURE CROP PROTECTION - INTERACTIONS WITHIN THE INDEPENDENT SECTOR: PRESTEL FARMLINK

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ABSTRACT

The activities, roles and prospects in future crop protection of the independent sector, specifically Prestel-Farmlink are discussed. Comparisons are made with other media, the agrochemical industry, independent crop consultants, on-farm computing companies and ADAS which provide information and advice to farmers. Modern farmers in the UK are identified as being remote from information sources but with high information needs requiring fast access to volatile crop and pest information from a wide range of sources. It is suggested that current overlap between competing media makes it difficult for farmers to carry-out the ideal of 'one-stop shopping' for all categories of information, computing and advice. The Prestel-Farmlink system is put forward as the natural system of the future in a rapidly changing and increasingly competitive farming market.

INTRODUCTION

This paper will first briefly review the ways in which U.K. farmers obtain information and advice on crop protection, their merits and disadvantages. We will then consider what can be offered by independent Videotex systems such as Farmlink, and their advantages compared with other media. Illustrations of some existing and developing interactive pest control packages from the U.K., Australia and elsewhere will be given, followed by a discussion of the potential for independent on-line systems in crop protection in the future.

INFORMATION AND ADVICE FOR THE FARMER: REQUIREMENTS AND SOURCES

Existing and future advice and how it should be made available to the farmer needs to be evaluated in the context of the requirements of the market. The farming industry in the U.K. is dispersed over more than 200,000 units (= farms) and the farmer is rarely in his office during the normal working day. He is, therefore, often remote from many of the usual information sources but nevertheless has high information needs, requiring fast access to volatile crop, pest and disease information from a wide of sources. This variety information should ideally be made available to him with the minimum of delay and in a structured, managed and interpreted fashion.

The role of the Agricultural Development and Advisory Service (ADAS)

Needham (1986) in this meeting, has reminded us of the Government sources of pesticide and other information actually used by farmers. Amongst these, visits by, and other contacts with ADAS and industry personnel dominate. However, such a visit to a farmer is costly (c. £100/visit; Farmlink market research) and is an inefficient use of time by both parties. ADAS also uses a wide range of other information media, from personal visits of the short-term problem-solving ('fire-brigade') nature to the provision of general, regional non-interactive advice and information via Prestel-Farmlink and Agviser (I.C.I). Needham (1986) has previewed plans for future information technology within ADAS but showed that there is no planned interaction between farmer and ADAS computer data bases. Only advisers will have access to the computer. This apparent advance over the use of visits, the telephone and the mail is still of limited use when one considers the special features of the farming market outlined above. The increasing emphasis on charging for ADAS advice means that current and proposed services must be evaluated even more critically in an increasingly competitive market.

The independent crop consultant

This type of adviser offers a service dedicated to a small group of participating farmers, whose land may be surveyed by crop scouts to assess crop factors, pest, disease and weed levels etc. Personal visits and telephone information are often combined with the collation of farmers' records on a microcomputer operated centrally by the consultant. Among other benefits, this often enables each farmer to compare for example his yields and enterprise profits and with those of neighbours. Although such services are often costly, the consultant's advice is a synthesis of personal experience, an awareness of recent research trends and an up-to-date knowledge of ADAS advice and recommendations. As the average member of the U.K. British Crop Consultants Association advises only 35 clients, they receive a more personalised service than that which is available through other media.

Computing in the farm office

Scores of software packages are commercially available, providing guidance in crop husbandry, stock control, payroll calculations, ration programs, horticulture and so on. There is an enormous heterogeneity of hardware and software compatability among these competing systems which, coupled with the static, non-interactive nature of the information provided on disk, places them a long way from providing the complete service needed by the farmer.

The agrochemical industry

The commercial sector is still by far the most frequently-used source of advice and information for the farmer (Needham 1986) This transfer of information is achieved mainly from the visits of representatives to farms, supported more recently by the use by companies of Videotex systems such as ICI Agviser and Prestel-Farmlink. The high ranking of the role of the visiting representative is probably largely a reflection of the professional persistence of this sales force and is unlikely to be due to their provision of a balanced, unbiased service. Advice from this source, whatever its quality, will always be open to the criticism that its main aim is to sell more product. The Agviser system does permit direct interrogation of the data base by the farmer, while Consellor is accessed currently by ICI advisers only, so is not Videotex and does not permit direct interrogation by the farmer in his office. Like the ADAS plans for the development of information technology (Needham 1986), this remains a major drawback in requiring the farmer to visit the adviser who then operates the program. However, of all the current systems, Consellor (and parts of Farmlink, see below) does approach a definition, in pest control terms, of an 'expert' system. This is difficult to define precisely but is generally conceived a being based on expert system shells. They are interactive and based on artificial intelligence in which the user is given a diagnosis based partly on previously stored information from that user is given a diagnosis based partly on previously-stored information from that user and from other sources. In practice, there may be more 'intelligence' in some conventional systems than in so-called expert systems which might be construed as not 'expert' at all. Perhaps the user's ability to be able to probe the reasoning behind the various pathways is a practical difference between 'expert' and 'non-expert' systems. A more complete discussion of the components of expert systems can be found in Store et al. (1986). It is however, in the information-storage element that Counsellor differs from other UK systems apart from parts of Farmlink (see below). Its relevance in forecasting and risk assessment, in particular applied to disease epidemiology, is obvious.

THE PRESTEL-FARMLINK SYSTEM

The current Farmlink Videotex system offers the farmer a comprehensive farm management service which can be categorised as a) information b) communication and c) computing. The information available can be of a 'perishable type' (eg. weather forecasts, crop conditions, regional disease levels) and of a 'non-perishable' nature (e.g. encyclopaedic information, chemical uses, advertisements for goods and services). Communication includes the interactive Mailbox facility through which farmer can communicate with each other and with information providers (e.g. ordering fertiliser, fungicides etc). The computing section, which is growing fast within Farmlink, enables individual farmers to access interactive programs which interrogate the farmer, calculate such things as economic rations and pest control strategy and then produce a report, diagnosis or give advice. The newly-introduced milk marketing Board Dairyfax service is another example.

All these aspects of the service are almost instantaneously available and at most cost no more to access and use than the price of a local telephone call. Interaction between the farmer and the system requires access to a computer which is either a Prestel main-frame in London or Birmingham or a 'Gateway' computer which may run the programs independent of the Prestel main-frames. The service also encompasses 'Closed User Groups' in which a sub-set of subscribers may share and pay extra for a service offered by an information provider.

The Farmlink package in itself, however, cannot be considered a true expert system in that it does not in allow the farmer's responses to be stored. For this, a larger computer capacity would be required or the user would need a desk micro-computer to double as his Videotex terminal. However, as mentioned before Farmlink leads the farmer via a Gateway to external computers where stored information concerning the farmer's own farm can be accessed. The MMB Dairyfax service is a prime example of this. Having used this type of service, the farmer then returns with a single key stroke to the Farmlink main index and continues to make use of all other facilities already described.

The overall aim of the Farmlink service is to draw together all the diverse information and advice needs required by a modern farmer. There may be a case for only one such system in the U.K., making available all the information, communication and computing which a farmer needs without his needing to leave the office - 'one-stop shopping'.

Computing and crop protection within Farmlink: some illustrations

Research and development workers in crop protection acting as information providers for Farmlink or other Videotex systems, may find the area with perhaps the greatest potential to be the provision and development of interactive pest and disease packages. Ideally, these help the farmer interpret the consequences for yield and economics of the changing situation on his crops. A system which approaches an expert system, as defined above, would be ideal especially for disease and pest management. Two pest systems developed at Southampton under contract to Farmlink are described below. The first concerns aphids on wheat and has operated for two summer growing sessions. It has been described fully elsewhere (Mann & Wratten et al. 1986, Mann et al. (1986). A flow diagram of this Aphid Control Program is shown in Fig.1. The advisory model is based on research on the aphids Sitobion avenae and Metopolophium dirhodum carried out at Southampton University over 10 years from 1975 to 1985 This is described fully in Watt et al. 1984, Wratten et al. 1984, Holt et al. 1984, Mann & Wratten, 1986 and Mann et al.(1986).

The aphid advisory model

The program predicts the damage that an aphid infestation may inflict on a crop of winter wheat. It takes information about a specific field of wheat at one time, adds the economics of control and, on the basis of the predicted aphid population, advises the farmer on a rational control policy.

The program is designed to be simple to use but safe in that it cannot miss an aphid outbreak and at the same time avoids prophylactic or "calendar" spraying. By calculating the highest possible growth rate for the aphid population at each plant growth stage, it cannot miss an outbreak by underestimation. It is likely, however, that maximum growth rates will not occur (due to weather, predators, etc) so the user may be asked to reassess the situation a few days later. If and when economic losses are about to begin and these exceed costs, spraying would be advised.

Field sampling for the program is easy and not time consuming. Aphids are not counted. A good relationship exists between the number of aphids per stem and the percentage of stems infested (Rabbinge & Mantel 1981). By simply examining 50 stems in a diagonal across the field for the prescence of each species, the percentage of stems infested can be calculated. This is then fed into the program together with economic details of the crop. The program replies almost instantaneously with one of the three advice categories. The advice given includes a statement of the economic benefits to be expected by following the recommendations.

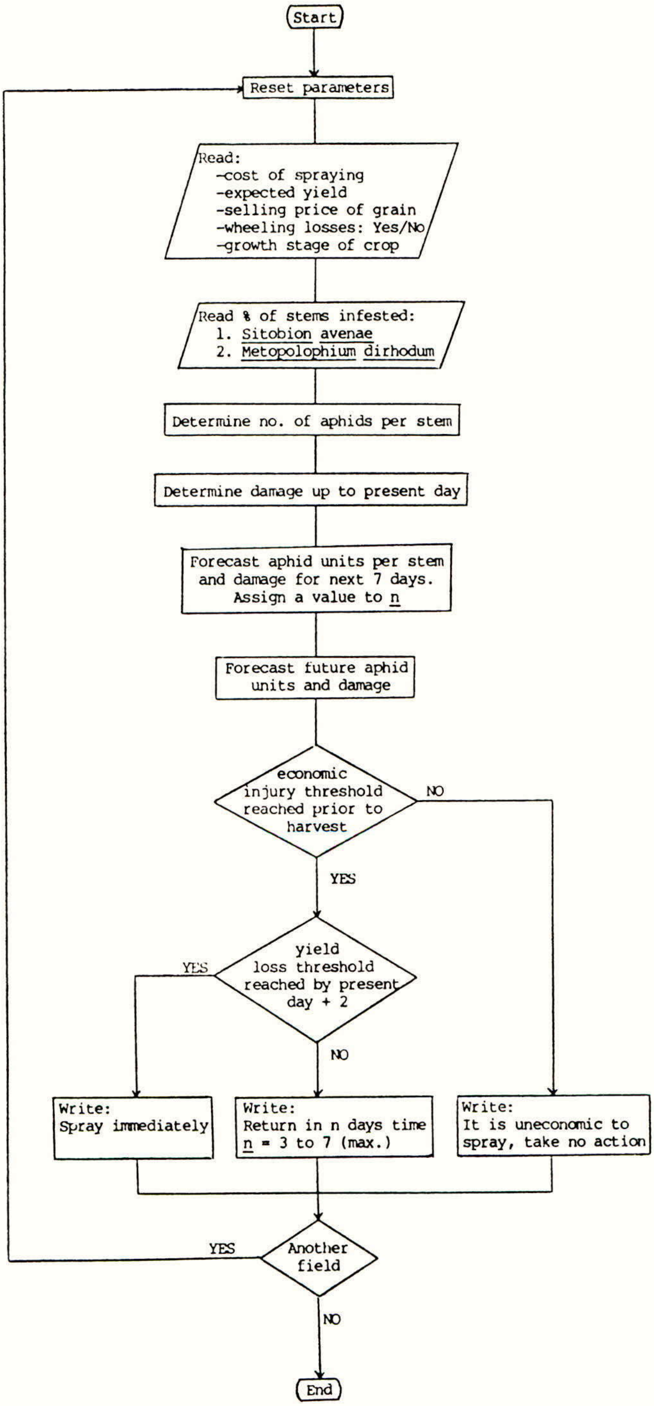

Fig.1. Flow diagram of the Aphid Control Program

During 1985, field work was carried out on a farm near Stockbridge, Hampshire, to compare the yield response from spraying according to the ADAS thresholds with the advice given by the model. However, numbers never rose above 4 aphids/stem for S. avenae, and M. dirhodum was rare; consequently spraying was never advised by either method. Further work is being carried out in 1986.

The model was run with data from other sources during 1985 and although it advised spraying in a small number of cases when spraying would not otherwise have been carried out, it would have prevented a great deal of uneconomic spraying situations where a prophylactic treatment was applied. In no case did economic losses occur when spraying was not advised. The model was most important with a late aphid infestation, when economic losses would have occurred if spraying had not been carried out; in these cases the model advised spraying but the ADAS threshold did not. The model is not based on a more or less fixed numerical threshold of aphid numbers and has the added advantages, compared with the ADAS advice, that it gives the economic basis for its recommendation. It effectively operates on an almost infinite number of thresholds in such a way that the farmer cannot easily make a rational guess at the advice it is likely to give.

In August 1985 a reply-paid card questionnaire was sent to several hundred farmers in south-west England (the only region covered by Farmlink at the time). Eighty-seven percent of those who replied found the program useful.

The model first became available to Farmlink subscribers on 17 June . By 31 December 1985 a total of nearly 1200 entries had been made to the program, averaging 6 per day. During this time Farmlink had an average of about 800 subscribers, so during the aphid season (June-July), there were c.28 uses/day.

Pest control program for oilseed rape

A more complex pest situation exists on rape than on summer cereals with three major spring and summer pests potentially causing high levels of damage. The pests are: blossom beetles (Meligethes spp.), the brassica pod midge (Dasineura brassicae) and the cabbage seed weevil (Ceutorynchus assimilis).

Although damage thresholds for rape pests exist they are static. More importantly, due to the growth characteristics of rape, the crop can compensate for a large amount of damage, particularly if it occurs at an early stage (Tatchell 1983, Williams & Free 1979).

A new model is currently under development at Southampton University. It is based on work published and being carried out at Southampton. Current work includes the effects of size and timing of the pest populations on yield loss and the degree to which oilseed rape can compensate such loss. The program predicts the damage that an infestation of these three pests may inflict on a crop of winter oilseed rape. It takes information about a specific field of rape, including sowing information, plant density and pest numbers, adds the economics of control allows for any possible plant compensation, and on the basis of the predicted pest population supplies advice on a rational control policy

(Fig.2).

Field sampling for the program is simple. The number of Meligethes spp. and C. assimilis per plant is sampled using conventional techniques (Lane, 1984). The number of D. brassicae is impossible to count and so a simple mathematical relationship is used, based on the number of C. assimilis, to calculate the maximum possible number of C. brassicae (Free et al. 1983)

During 1986 field work was carried out to compare the yield response from spraying according to the ADAS thresholds with the advice given by the model. The results are being analysed.

The future of Farmlink pest and disease packages

The two models described above are merely the first stage in the development of a series of advisory packages for Farmlink which are being developed at Southampton University. The type of package depends on the needs of the farming industry and on what research information is available; all packages will be tailored to the needs of the industry and changed or developed as necessary. At present, work is being carried out on the oilseed rape pest package. Future packages will include systems on sugar beet foliage and soil pests, Barley Yellow Dwarf Virus, pea moth and cutworm control and glasshouse pest control, among others.

At a time when pesticide inputs are being critically examined because profit margins are reducing and environmental pressures on the farmer are increasing, such packages implemented through systems exemplified in Prestel-Farmlink should prove invaluable to the modern farmer. Also the concept of a single, static, numerical threshold of pest numbers is increasingly unrealistic as better-quality damage-assessment data become available. A farmer cannot be expected to be up-to-date and so familiar with such research that he can apply it immediately. The old media through which such information was made available to growers (see Introduction) are becoming increasingly restrictive? Interactive packages, similar to expert systems in their method of operation, are certain to be a major part of future crop protection. Although progress in the U.K. is relatively rapid, development of information systems is taking place on more than one front. The case, for 'one-stop-shopping' for farmers is a strong one, with penetration into the farming industry proceeding unhindered by overlapping and competitive systems. It is salutory to compare progress with that in France; there the TELETEL videotex communication network, which consists of a MINITEL terminal and an optional TANSPAC (PSS) system, is receiving rapid acceptance by farmers. About 15,000 terminals are currently installed on French farms and double this number of farmers are expected to be users within the next 4 - 5 years. Impressive progress is also being made in other European countries, as well as in Australia (e.g. the SIRATAC cotton pest management system - Hearn & Da Roza, 1985) and in the U.S.A. We believe the Prestel Farmlink system to be the natural information, communication and computing service for the future. Of all other systems it meets more closely the criteria increasingly in demand by the dispersed farming community with its need for rapid access to volatile crop protection information in a rapidly-changing and increasingly competitive market. From the farmer's point of view, the current range of competing systems is confusing. The time is right for all services to be made available on one

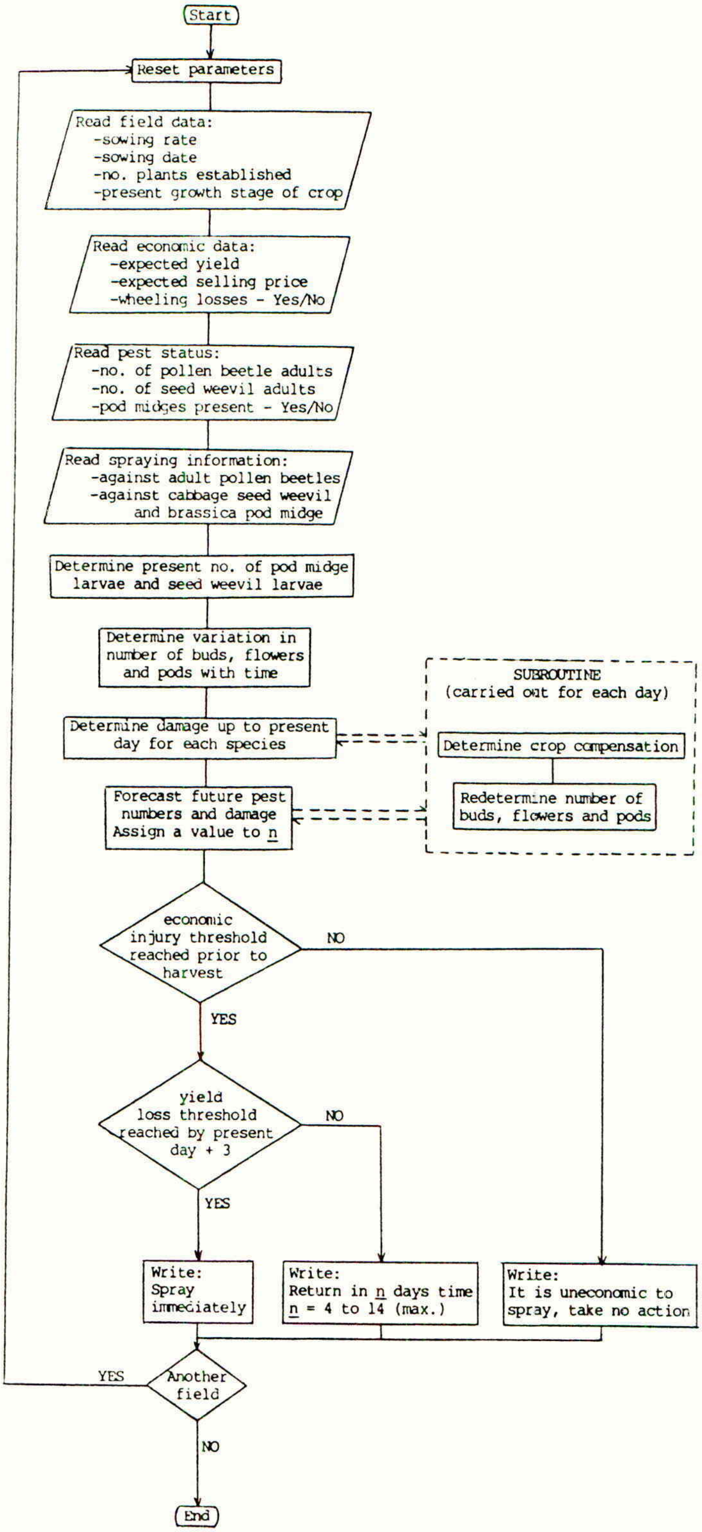

Fig.2. Flow diagram of the oilseed rape Pest Control Program

managed system.

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A DUTCH PERSPECTIVE OF COMPUTERIZATION IN CROP PROTECTION

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ABSTRACT

In the Netherlands, penetration of local computers in the larger agricultural enterprises was about 18% in 1985, with many process computers and relatively few PC's for administrative purposes. The use of distant computers, shared by many clients, is extensive, even though the various objectives are disconnected. The Dutch approach to agro-information technology emphasizes the demand-side rather than the supply-side. As a consequence, a collectivization of this technology appears, which leaves but limited scope for private initiative. Doubts are raised as to the comparative advantage to farmers of agro-computerization. Considerations are forwarded to improve the value of computer-generated decision support for agricultural entrepreneurs.

INTRODUCTION

The famous German poet Heinrich Heine said, more than a century ago: 'When the world will perish, I want to be in Holland, because there everything happens fifty years later'. In automation affairs, fifty years equals infinity. A small delay, however, with things happening slightly later, could be an advantage in view of the dialectics of progress.

A survey of agro-automation in some foreign countries gave Dutch authorities the impression that uncoordinated supply of information technology to growers might create great confusion among them, a terrible mess of incompatible systems, and - in the end - standstill rather than progress. Rejecting this supply-side automation, they looked for another approach.

PENETRATION OF COMPUTER USAGE IN DUTCH AGRICULTURE

Local computers

Let us first consider some facts from a 1985 sample survey on the penetration of computers in Dutch agriculture (Table 1), considering only the larger units. Horticulture ranks first with process computers used to control glasshouses. Dairy farming is second, with process computers for automized cattle feeding. Only about one in twenty growers, in horticulture and in arable farming, use personal computers for administrative purposes. Before 1988, the number of administrative computers is expected to double. In 1990, the number of personal computers in the Netherlands is expected to be 1.5 million, more than one per ten inhabitants, of which - I guess - some two percent will be in agriculture.

Distant computers

Table 1 grossly underestimates computer usage in Dutch agriculture because it refers only to the category of local computers, on-farm computers for process control and administration. The table ignores the category of distant computers, whose use is shared by a great number of clients, either by direct access as in VIDITEL (the Dutch variant of Prestel), or by indirect (or mediated) access through telephone or mail. A major example is the national registration system for dairy cattle used to select the best sire for every individual cow. In crop protection, the example is - of course - EPIPRE.

TABLE 1

Computers in Dutch agriculture, 1985, according to a sample survey (Amro Bank 1985, 1986).

Branch	Type of computer	Number of holdings	Computers	
			number	%
Horticulture		9,500		
	process		5,200	55
	administration		730	8
Dairy farming		43,200		
	process		5,300	12
	administration		0	0
Arable farming		11,000		
	process		0	0
	administration		550	5
All		63,700	11,780	18

Crop protection

EPIPRE (the acronym of EPIdemiology, PREdiction and PREvention) is a decision support system for crop protection in wheat, using a distant computer (Rabbinge & Rijsdijk 1984, Reinink 1984, Rijsdijk 1983, Zadoks 1984a). It covers the aphid pests and six fungal diseases, encompassing soil type, variety, sowing date, nitrogen status and host development. It is interactive, as farmers can ask for recommendations at any time; the recommendation is based on past treatments and actual field monitoring data. EPIPRE is deterministic as it gives a single answer with documentation to let the farmer make his own decision. The system does not answer WHY questions and it is ill suited to answer IF-THEN questions, so it has not the interactive capacity of an expert system. A Dutch expert system for crop protection in wheat is in an incipient stage only.

EPIPRE participants number about 500 per year, with some 1000 fields. There are some 150 permanent participants, but most farmers participate for about three years to learn the tricks of the trade. The learning effect is more appreciated than the financial effect (Blokker 1983, Zadoks 1984b). In the past ten years some 3000 farmers must have been exposed to EPIPRE. This figure, related to the about 11,000 larger arable farmers, suggests a penetration of over 25 percent. In 1986, EPIPRE has been extended by adding recommendations on nitrogen top dressing and on the use of straw shorteners.

EPIPRE is also available for personal computers, for wheat and for barley, but commercialization is not yet attractive, in part due to government competition. Government competition does not yet exist in the area of weed control, where a few private companies sell programs based on work by the Research Station for Arable Farming and Field Production of Vegetables (PAGV) at Lelystad (Aarts & de Visser 1985). The agrochemical industry has not yet deeply penetrated the Dutch market for crop protection software.

THE DUTCH APPROACH TO INFORMATION TECHNOLOGY

Having surveyed the facts, we may proceed to opinions. In the seventies, Dutch public opinion was sceptic about the utility of large-scale computer application. The trade unions were squarely against it. Accordingly, government was slow to act. Belatedly, after several small steps each ending in a report, government began to stimulate information technology. An INformation technology Stimulation Program (INSP = Informatica Stimulerings Plan; Staatsdrukkerij 1984) was submitted to Parliament in 1984. The Minister of Agriculture took a long-term share of over 200 million guilders in INSP-Agro and proclaimed computerization in agriculture the official policy.

A coordinated approach was advocated, stimulating the demand-side rather than the supply-side. Representatives of the growers and of the Ministry formed a Committee for the development of automation in agriculture, COAL. The actual work was entrusted to five Branch Organizations which represent the interests of the growers. The Branch Organizations have to list minimum requirements for software, for example with respect to the use of units and to the compatibility between software packages. Certification of commercially offered, supply-side software is envisaged.

My personal assessment of today's situation is that INSP-Agro led to much talk in inner circles, the publication of reports with beautiful flow diagrams, but few tangible results. Some decisions even seem to have been delayed.

The strong official emphasis on the demand-side has not completely suppressed the supply-side. Crop protection played its part through EPIPRE. It was initiated in 1976 by the Agricultural University, rather as a scientific challenge. When that challenge was met and EPIPRE was transferred in 1981 to government for routine application, the initiators started a private company named FYTOCONSULT to capitalize on the knowledge acquired. Within a few years this company became the agro-software developing branch of the Dutch organization of farmer cooperatives, Cebeco-Handelsraad. An early product is the farm-management package COMAK into which crop protection elements are being integrated. Also, a data base of diseases and pests and of their treatments is now available for horticulture, presently only for restricted use.

As the cooperative organization, which represents about half of the Dutch agro-market, has capital to invest, the thrust of commercial automation in agriculture appears to be there. As the cooperative organization is property of and supplier to the farmers, it is in the ideal situation to match the supply-side with the demand-side, with emphasis on the demand-side.

Several private companies have entered the agro-software market. In the area of crop protection, weed control is a favourite topic. The usual strategy is to incorporate a weed control module into a larger crop management package.

FUTURE DEVELOPMENTS

Prestel-type networks for agriculture are being developed, with present emphasis on marketing aspects. In 1986, a trial run was made for crop protection in the orchards of the River District (N. van der Lee, pers. comm.) to supplement and eventually replace the automatic telephone answering service (29,000 calls in 1986). The crop protection page seems to have been consulted some 5,000 times during the summer months of 1986. For 1987, a regional project is planned for arable farmers, to be presented as a crop management package including modules such as EPIPRE and the PAGV weed control program. Unfortunately, much of the information supplied is rather like old wine put into new bottles. From general services by distant computers, I expect little improvement over the present situation.

Real improvement can be obtained where distant computers offer specific services in an interactive mode. General knowledge can be matched to farm--specific, field-specific, or animal-specific data so that new information is generated for more cost-effective management. Examples are
(1) SAP (Sire Advise Program of the Royal Netherlands Cattle Syndicate, which encompasses about 7.5 million cows (4.5 million living cows) and 100,000 bulls,
(2) COMZOG, originally designed by a farmer, managed on a distant computer by LARC (a subsidiary of the cooperative organization), providing veterinary and zootechnical recommendations for over 55,000 production sows from 320 farms, with economic analysis per farm, and
(3) in crop protection, EPIPRE, giving recommendations to about 400 farmers, for nearly 800 fields, covering about 6,000 ha (1986 data).

Though much attention goes into the implementation of distant computers as decision support tools for farm management, there is a disadvantage. The farmer has to consult different distant computers for different types of decisions. This can be remedied, but my feeling is that the future is to the local computer with integrated software. With integrated I mean the following.

Treatment options should consider past cropping plans (rotation aspect), appear in the farmer's diary (timing and opportunity costs aspects), refer to the stock of pesticides (inventory aspects), and their prices (cost aspect), and check future prices (benefit aspect). The decision made and executed, the action should be registered in field, crop, stock, time and finance accounts.

Dutch farmers ask and accept advice, but few of them will take pride in a situation where others, let alone computers, will make their decisions. It would be against their entrepreneurial feelings. These feelings may induce the desire to own the computer with the software and to be the master. Apart from the psychological argument there are two other arguments in favour of local computers, one technical and one managerial. The technical argument is the fading-away of the distinction between process computer and administrative computer. Processing data can be incorporated in the administration and accounting sectors of the program whereas external information can influence the process. One company is marketing computer compatible weather stations for crop management purposes. The managerial aspect in favour of the local computer is obvious. The entrepreneur often faces new and unexpected situations where distant computers would be of even less avail than local ones.

The extension aspect of the new information technology, or the packaging of the message, is under study. A thesis on the subject was published in the Netherlands (Blokker 1983). In crop protection, EPIPRE experience indicates that farmers like fact-based options, each with a price tag, together with a recommendation for treatment including the active ingredient(s) to be used. Though farmers may have good reasons not to follow the recommendations, acceptance of the EPIPRE recommendations gradually rose from 30% to 70%, an advance partly due to improvement of the message and of its delivery.

COMPARATIVE ADVANTAGE OF COMPUTERIZATION IN AGRICULTURE

My major personal concern is the comparative advantage of computerization in agriculture. Apart from following the stream and from possible economics of scale, what do we gain by computerization? For process computers there is little doubt, purchase being a matter of economics only. Some distant computers (e.g. for pig and poultry feeding) have process computer characteristics. Good documentation, combined with technical and economic inputs, may lead to improved efficiency. The comparative advantage of EPIPRE is said to be its site specificity. Nevertheless, its financial profitability was questioned (Blokker 1983, Zadoks 1984b).

What is the comparative advantage of distant computers? Interactivity is absent or, at best, mediated. Speedy supply of the most recent information is an advantage indeed, but the gain upon present news services is measured in hours only. The major advantage is rapid updating for all users, e.g. when a new rust race appears or when a pathogen suddenly shows resistance against a fungicide. Readability is poor, storeability is nil, unless the farmer has his own printer connected. Information systems which merely supply information are easy to make. The information can support decisions, but information systems are not decision support systems, and certainly not expert systems.

I think that the comparative advantage of computerization will appear only where general knowledge is matched to the specific situation of the user. Just one example of matching is the following: when yellow rust (*Puccinia striiformis*) on wheat escapes control for some reason EPIPRE will recommend not to apply a top dressing of nitrogen. The matching process has always been left to the farmers themselves, though they could seek advice. Obviously, they made the match quite skillfully, but further progress demands scientific inputs. My own experience is that present science has little to contribute to the matching process. The parameters needed to implement EPIPRE and even some of its basic concepts could not be found in the literature. So, let me rephrase the problem bluntly: "How can the farmer make more profit by paying more for software?" This is a new challenge for the crop protection scientist.

CONCLUSIONS

To hasten slowly may not be the most typical aspect of the Dutch approach, as computer technology was effectively applied to crop protection from 1977 onwards.

Typical for the present situation is the emphasis on the demand-side. This emphasis is phrased by agricultural authorities representing farmers' organizations and government, as well as by the organization of cooperatives. Both entities represent supply *and* demand. INSP-Agro combines highly formalized demand with scientific supply by research institutes. The organization of cooperatives combines demand, as it represents about half the market, with supply, as it is the holding company of a few software subsidiaries. The total picture is one of collectivization of information technology, through INSP--Agro in a more sophisticated manner, through the cooperatives in a more down-to-earth style.

In comparison, the results of various private companies are limited even though ambitions run high (Stam 1986). Crop protection is certainly not their highest priority. Crop management packages, including crop protection modules, are being developed for local computers, in partial association with the European EUREKA project (H.F.M. Aarts, pers. comm.).

The new technology is gradually penetrating all aspects of agricultural activity in the Netherlands, but really interactive systems are still the exception. Extension science will have to make great efforts to reprocess existing messages. Crop protection science is challenged by the problem of efficacious matching of general knowledge and specific requirements, a hard nut to crack if the outcome is to make the farmer more efficient in crop protection, with maximum benefit and minimum risk. Only then will information technology provide added value to crop protection.

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