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PRESENT SITUATION AND FUTURE TRENDS IN RESEARCH IN PLANT PROTECTION

FRANZ J. SCHWINN (*)
Research and Development Plant Protection - Agricultural Division - Ciba-Geigy Ltd., Basle

Introduction

Before discussing the future I should like to briefly describe major factors supporting today's agriculture. the four most important tools: mechanization, plant breeding, fertilization and chemical plant protection have contributed, where available, towards doubling of yields worldwide between 1950 and 1980 and towards further continuous increase of agricultural productivity and improved quality of agricultural commodities. This development has mainly taken place in the industrialized world, i.e. in North America, Western Europe, Japan and some other countries in Southeast Asia. The forementioned successes are largely based on four elements:

1. ***Plant breeding*** has produced new crop varieties with better quality and higher yields: in addition, adaptation to climatic conditions has been strongly improved. As an example, the increase in cold resistance of maize has allowed cultivation of this crop in large parts of Europe including prealpine areas leading, together with intensive animal breeding, to a new agricultural production system. However lately such practices have also revealed disadvantages: soil erosion in maize and a manure disposal problem in certain areas have raised public concern.

2. ***Mechanization*** has contributed most to the increased productivity of agriculture. Labour was reduced significantly, mechanical soil work permits control of weeds, rodents and insects, and a fine seed bed gives optimal starting conditions to crop seedlings. Today we realize that the use of heavy machinery may result in soil compaction, and a fine soil preparation favours erosion by wind or water.

(*) Head Biology.

3. ***Fertilizers*** are ideal tools to increase the yield potential of a given soil or to balance its nutritional status by selective amendment of the required elements. Despite this exciting potential, their excessive use has resulted in contamination of rivers and lakes, and an increase of nitrates in drinking water.

4. ***Chemical plant protection*** agents have proven to be reliable, potent and economic tools to increase yields or to protect the farmer from losses due to weeds, insects or diseases. Their obvious benefits have undoubtedly stimulated their widespread use which, however, has also led to some negative consequences such as the occurrence of resistance or their presence outside of target areas, such as rivers or groundwater.

The present status of chemical plant protection

Thirty years of extensive and innovative research have led to considerable improvements in terms of activity, selectivity and environmental safety (Figs. 1, 2) of the products. Simultaneously, the standards and requirements for registration have steadily increased (Fig. 3). Thus, overall the safety for users of the products and consumers of agricultural produce has been largely improved, a fact which is often overlooked in discussions in the public.

1960's		1990's
simple structure	active ingredient	complex structures, natural products
broad, protective	biological activity	specific, curative
calendar-based	application	when needed (IPM-based)
kg/ha	dose rates	g/h

Figure 1 — Major changes in chemical plant protection.

Despite this overall very positive conclusion we must also point to a range of problems connected with chemical plant protection. They are partly of technical, partly of emotional nature, and they can be characterized as follows.

Technical problems:

- — the control of perennial weeds in annual crops and of volunteer plants
- — the control of wilt and soil-borne pathogens
- — the control of diseases caused by bacteria, mycoplasms and viruses
- — the control of thrips in greenhouses and planthoppers on tropical crops
- — resistance of pathogens, insects and weeds against chemicals
- — the lack of tools for better targetted application.

Qualitative Growth 1960-1990

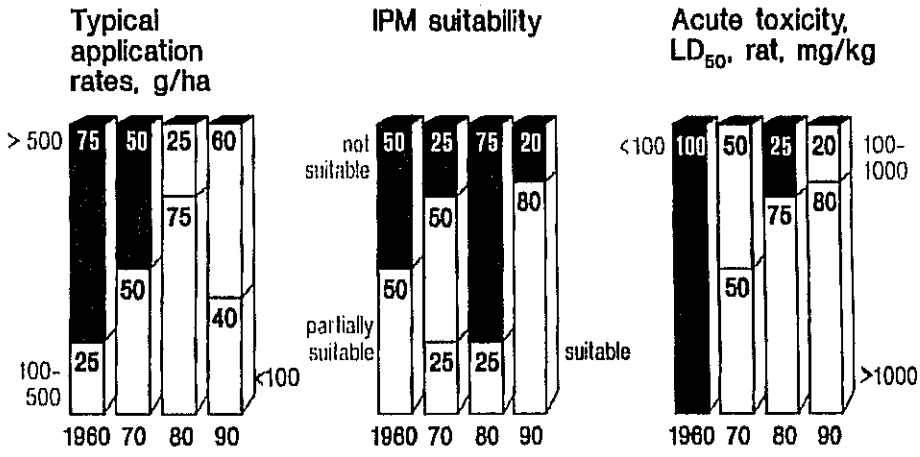

Figure 2 — Insect control, development products (*Agricultural Division*).

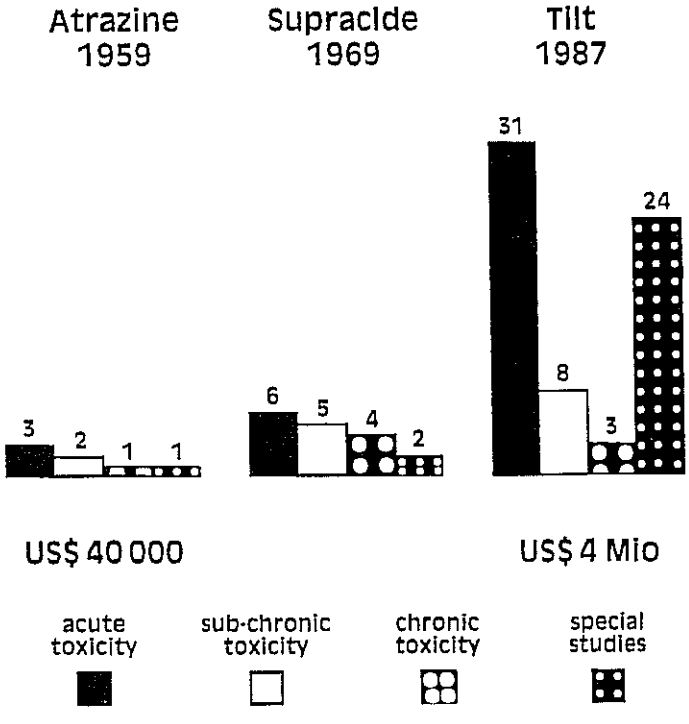

Figure 3 — Number of tox-studies for registration in the US.

Emotional problems:

— the fear of intoxication by consuming chemically treated product. Despite a broad data basis showing the high level of safety of plant protection chemicals (Fig. 4) and an overall favourable residue situation on food crops and their edible produce, the public, which has to a large extent lost contact with nature and agriculture and their inherent rules, perceives chemicals as a health threat, despite steady increasing lifetime expectations.

- Out of 19'000 food samples analyzed only 2.6% contained residues of plant protection chemicals above the legally tolerated level:
  - — in domestic fresh fruit 0.3%
  - — in imported fresh fruit 3.5%
  - — in baby food 0%
- The legally tolerated residues are based on a safety factor of 100-1000.
- Conclusion: no real threat.

Figure 4 — Residues in human food. German society for nutrition, annual report 1988.

Even this short list of open topics would offer enough opportunities, challenges and objectives for future research in plant protection. However, in a sense, this would only be a linear projection of the past, and experience learns us that the future is never of this nature. Therefore, we have to consider additional factors, such as

— changed values, priorities and requirements of our society

— new scientific and technical developments, such as chiral chemistry, natural chemical products, genetic engineering

— changes in agriculture towards integrated production, novel farming systems, etc.

Sketching the future of plant protection

From a global viewpoint it is obvious that in view of the ongoing increase of the human population agricultural production must be further increased considerably. Since arable land is limited and multicropping is only possible on a minor part of it the potential for the required increase (1980 → 2000 = 100%) lies in higher yields per surface unit. Despite these clear worldwide objectives agriculture is operating in a broadly different regional framework and confronted with controversal issues, as a shown in figure 5.

Focussing on agriculture in the industrialized countries, i.e. Western Europe and the USA, there is a clear, society — and economy — driven trend away from the so far dominating objective of profit maximization towards

Changed business and social environment		
Overproduction of food	vs.	inadequate food supplies, starvation
Environmentally acceptable chemical processes and product safety	vs.	activity and lowest input cost of agrochemicals
Inverse logic		
Cry for fast replacement of old products	vs.	increasing hurdles for registration of new products

Figure 5 — Challenges of agriculture.

optimization of production, i.e. towards a rigid cost-benefit evaluation of all system inputs. For the chemical industry this means no longer search for perfection of biological performance but rather for economically adequate solutions. In addition, new and higher ecological requirements have to be fulfilled by future products.

As you all know, industry and our profession are facing a major problem, i.e. dealing with perceived problems of the layman. As scientists, be it in industry or academia, we are not used to discuss technical problems from an emotional angle with the layman who feels threatened and who hears contradictory statements about the need for chemical plant protection and problems of food safety by specialists and politicians. I am sure that we must put much more emphasis on dealing with these concerns.

In our view crop protection will move towards a broader integration of various different control measures, as shown in figure 6. Of course good crop husbandry always comprised more than just one approach, even so we must admit that in the past the ease and reliability of chemical control has sometimes led to a neglect of other valuable elements of crop protection. Integrated Crop Protection (IPM) will increase in practical importance, certainly at a pace which may be slower for some crops than for others. CG accepts this concept and supports it actively by different R&D projects and activities; some of them are shown in figure 7.

In connection with IPM it is sometimes felt that there is no room for chemicals in this concept, because alternative methods are claimed to be able to solve the problems. The alternatives meant here are: biological, physical, agronomical and breeding methods. In our evaluation, which we based on discussions with experts in many countries, the mid-term potential of these different methods is as follows (Figs. 8-11).

In conclusion, these methods are considered as absolutely valuable elements of IPM, which, however, for the foreseeable future will need the continued support by chemical products.

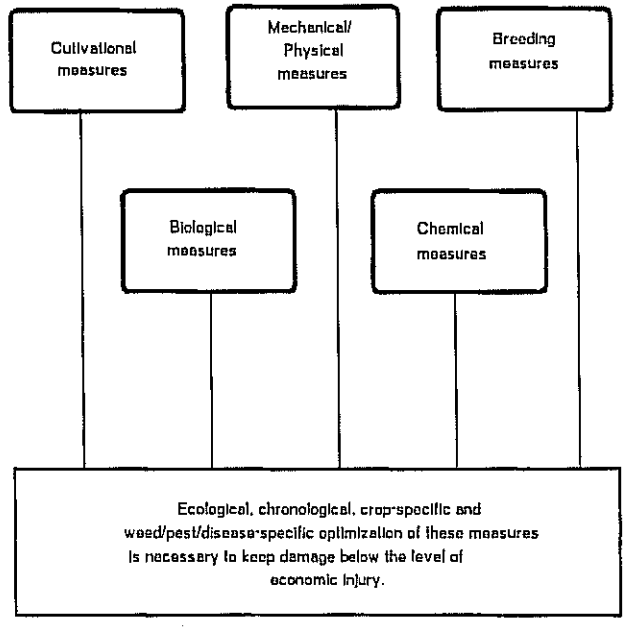

Figure 6 — Components of Integrated Pest Manangement.

- Improved use parameters for the present commercial insecticides (timing, dose rate, targetting) by longterm investigations on field populations of insect pests and beneficials
- Adaptation of biological evaluation of new products to criteria of IPM
- Higher inherent selectivity and high environmental and human safety of new chemicals
- Development of commercially feasible biologicals
- Development of tools for early detection of diseases (diagnostics)

Figure 7 — Contributions by industry towards IPM inputs.

Objectives for R&D in chemical industry

In conclusion, the objectives of crop protection research at CG can be formulated as shown in figures 12 and 13.

The numerous options for ameliorating the efficiency, safety and ecological acceptability of plant protection chemicals are actively pursued at many levels and will contribute to maintaining this technology as a reliable and indispensable future element of crop production.

Problem	Present status	Future trend
weeds	insignificant	increasing research efforts
insects	minor uses in practice in selected areas/crops	substantial increase of research efforts; will gain importance in practice
pathogens	efforts on research level, so far no practical significance	increasing efforts and importance

Figure 8 — Alternatives to chemical plant protection: *biological control.*

Problem	Present status	Future trend
weeds	little practical importance (except control through burning)	slight increases
insects	apart from soil sterilization by vapour and sterile male techniques insignificant	no major change
pathogens	apart from soil sterilization by vapour modest successes in isolated areas (pruning)	insignificant

Figure 9 — Alternatives to chemical plant protection: *physical control.*

Problem	Present status	Future trend
weeds insects pathogens	significant support activity but non substitute	practical role strongly depending on economics (incl. energy)

Figure 10 — Alternatives to chemical plant protection: *cultivational methods.*

Problem	Present status	Future trend
weeds	insignificant	insignificant
insects	significant for certain pests	strongly increasing with progress of genetic engineering
pathogens	significant for certain pathogens	strongly increasing with progress of genetic engineering

Figure 11 — Alternatives to chemical plant protection: *plant breeding for resistance.*

New application techniques, such as seed treatment, encapsulation, spraying films will receive more research attention.

In addition to our efforts towards new chemicals we have an active interest in the discovery and development of biologicals, be they used as a living or

1. Slow substitution of chemicals by biological agents or transgenic plants in certain segments	→	continuing chemical support
2. Selective mode of action	→	basic research biochemistry
3. New approaches to pesticide design	→	biorational design and modelling
4. High inherent activity	→	specific target sites
5. Fast biodegradation	→	natural products
6. More complex chemistry (stereoisomers: more production steps)	→	smaller number of new lead structures
7. Safer production cycles	→	new processes

Figure 12 — Trends in R + D for the 1990's.

1. *Synthetic plant protection agents*
   - low application rates, adequate specificity
   - safe for man and environment
   - fast degradation
2. *Natural products and their analogs*
3. Development of *natural or modified antagonists* for biological control of pathogens, insect pests and weeds
4. Fit of existing or new products into advanced *techniques of integrated crop management* (new application techniques, delivery systems, formulations etc.)
5. *Pest-specific protection techniques*, e.g. immunization of plants against diseases.

Figure 13 — Integrated plant protection technologies of the 1990's: R & D targets.

as dead organisms. Whilst the use of such products has already proven useful in some cases in insect control, such as Bacillus thuringiensis, research in the fields of biocontrol of pathogens and weeds is still in its infancy. In my view, it is wrong to raise hopes and illusions in the public about the short — to mid — term use potential of such products. We are convinced that they will only be accepted by the farmer if they reach a useful level and high reliability of action. This means that parameters like stability, shelflife, speed of action, independence from climatic factors still require a lot of attention, brains and innovative solutions before commercial products against major pathogens will be available at the farmer's level. Short — to mid — term I see their chances above all against otherwise hard to control pathogens and their application in closed systems such as greenhouses.

More emphasis will be put on research towards biologicals, as far as they prove active, reliable and economically viable. We are confident that biotechnology will significantly improve the performance profile of biological inputs.

However, since these improvements will be transformed into practical solutions only stepwise and slowly, their intelligent combination with other inputs, including chemicals, offers the most promising strategy for the foreseeable future.

CG as a worldwide leading company is investing considerable funds into R&D in plant protection. We have been successful in the past, we are prepared to accept the challenges of the new objectives as lined out, and we are confident that we will be able to further contribute to the objectives of a targeted, ecologically safe and economically sound concept of plant protection.

Indirizzo dell'Autore

Research and Development Plant Protection - Agricultural Division - Ciba Geigy Ltd. Basle, Switzerland.