Herbicides Active in the Chloroplast

International Workshop at Monheim, Germany, August 13–15, 1989, in honor of the 60th birthday of Achim Trebst

Preface

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A diversity of plant processes and biochemical reactions is involved in herbicide action that leads to selective kill of weeds within the crop. Uptake of the herbicide through leaf cuticle or root, transport in the plant body, its metabolism together with its translocation in the cell, and eventually the interference with the target site will determine the phytotoxic effect and selectivity of a compound. We are far from understanding this complex functional interplay, and – admittedly – up to now new herbicides have been found by greenhouse screening with intact plants. The investment of industry into this costly key activity of herbicide research and development is quite impressive. The long-term goal in herbicide development, however, is to know the effect(s) of xenobiotics on the basic plant processes mentioned above. A future synopsis of their functional details may enable us to make predictions on herbicidal properties of new structures thus contributing to a (more) rational "chemical design". Appropriate unicellular and multicellular model species as well as cell-free biosynthetic assays and enzymatic studies on the mode of action and metabolism are necessary to gather the relevant data for such an approach.

Undoubtedly, active compounds are powerful leads for herbicide development, and in the last decade research on mode of action has provided a stimulating impetus in both industry and academia. Industry considers mode of action research as a long-term asset for future drug and inhibitor design. Research has been strengthened by the prospects of engineering herbicide resistance into crop plants by molecular cloning. The target in the cell and its properties towards herbicides must be known when it shall be altered genetically. Furthermore, an alert public will ask for more information on herbicide action than some years ago, as will do the registration agencies. Essentially, mode of action studies will help to mature chemical weed control as an acknowledged field of science. In basic research, on the other hand, herbicides are used as specific probes to characterize certain reactions in plant bioenergetics or biosynthetic pathways. By inhibitor studies knowledge in plant biochemistry has been widened or even established, as demonstrated, *e.g.*, by photosynthetic electron transport or pigment biosynthesis studies.

As emphasized time and again, new phytotoxic compounds to be developed should interfere with specific plant processes but not with general biochemical reactions. Accordingly, the chloroplast is the organelle of choice as it is the site of light energy conversion, of photosynthetic electron transport, pigment and fatty-acid biosynthesis, and the production of essential amino acids. Modern herbicides find their site of attack here. This workshop dealt with the biochemistry of plastidic functions and their interference with inhibitors. It was the fourth gathering on this topic, starting in 1979 in Konstanz, Germany, then held 1983 in Wageningen, The Netherlands, and 1986 in Lake Placid, New York State. As in this case, contributions of the previous workshops have been published in special issues of Zeitschrift für Naturforschung, Section C [Z. Naturforsch. **34c**, No. 11, 1979; **39c**, No. 5, 1984; **42c**, No. 6, 1987]. The organizers express their gratitude to the publisher for this issue, again making it commercially available separately from subscription.

During the two and half day meeting at Monheim 21 talks were given and 48 posters presented to an audience of 110 participants, mostly from European universities and international chemical companies. The contributions are grouped in five sections: (I) Photosystem-II inhibitors, (II) Binding site of photosystem-II inhibitors, (III) Resistance to herbicides, (IV) Interference with pigment and lipid biosynthesis, as well as peroxidation, and (V) Amino acid and nitrogen metabolism.

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Photosynthetic electron transport, particularly the biochemistry of photosystem II, dominated the meeting due in part to the foregoing 8th International Congress of Photosynthesis at Stockholm, which had been attended by many participants. Photosystem II is the prominent target site for a plethora of inhibitors of electron transport and of well-known successful herbicides. Furthermore, knowledge in photosystem-II biochemistry is quite advanced as compared to that of other sites of herbicidal attack. The "herbicide-binding protein" (the D 1 peptide) has been intensively studied in recent years in connection with resistance phenomena, photoinhibition and molecular genetics. A further reason to emphasize biochemistry and enzymology of photosynthesis was the 60th birthday of one of the leading scientists in this field, Achim Trebst from the Ruhr University, Bochum, Germany. The organizers and the contributing colleagues feel proud to dedicate this Workshop and this special issue in his honor.

Achim Trebst has made noteworthy contributions to chloroplast biochemistry over the past 30 years. He was one of the first investigators to publish on CO_2 assimilation by a reconstituted chloroplast system (in the laboratory of D. I. Arnon) and he is a recognized leader on the overall topological and functional organization and biochemistry of light-induced electron transport and energy conservation in thylakoids. His many contributions have elucidated the role of plastoquinone, ferredoxin, cytochromes and synthetic electron mediators in photosynthetic electron transport. Together with K. H. Büchel, W. Draber, and D. E. Moreland, Trebst has reported on the results of innovative structure/activity studies conducted with a large number of diverse chemical families that interfere with light-induced electron transport. Among the compounds studied were benzimidazoles, biscarbamates, triazinones, thiadiazoles, thiazolyliden ketonitriles, halogenated phenols, diphenyl ethers and others. The thrusts behind the structure/activity studies were to identify the site of action of the compounds and to extrapolate the observations to the design of new herbicidal candidates. Most noteworthy was the discovery and characterization of dibromothymoquinone (DBMIB) as a plastoquinone antagonist and inhibitor. The Mitchell theory and the mechanisms of transmembrane proton transport were elaborated and strengthened by his inhibitor studies. The current model of the structure of the photosystem II core and the herbicide-binding niche of the D 1 peptide was forwarded by Trebst by adapting the structural features of the reaction center from purple bacteria to oxygenic photosynthesis.

Gatherings like this at Monheim can trace their origin to the International Congress of Photosynthesis that was held in Freudenstadt, Germany, June 6–8, 1968. This Congress was the first of the International Photosynthesis Congresses. A. Trebst was a member of the organizing committee and arranged a section entitled "Action Mechanisms of Herbicides in Photosynthesis". This topic was considered as a breakthrough for inhibitor biochemistry in photosynthesis, and twelve papers were subsequently published in the Proceedings.

Trebst is one of the initiators of modern photosynthesis and inhibitor enzymology in particular. Many younger colleagues had the pleasure to work in his laboratory, starting their career under his guidance. Colleagues in Germany and abroad owe him a lot, they appreciate his scientific integrity, open-minded attitude and his steady willingness to communicate and to cooperate.

The BAYER Company hosted the meeting in its excellent facilities of the "Pflanzenschutzzentrum" at Monheim close to Düsseldorf. Due thanks are expressed to Prof. Dr. Dr. h.c. mult. K. H. Büchel, member of the Board of Directors, Dr. H. Krätzer, Head of the Agrochemicals Section and Dr. P. Kraus, Head of Biological Research, for hospitality and generosity.

The Organizers

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