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Ian Denholm graduated from Manchester University with a B.Sc. in Zoology in 1976, and from Liverpool University with a Ph.D. in Genetics in 1979. Since 1980 he has worked at the Rothamsted site of the UK Institute of Arable Crops Research (where he is currently Principal Research Scientist) investigating the origins and development of insecticide resistance in a range of arthropod pests. His particular interest is in identifying ecological and genetic factors that influence the selection and spread of resistance genes, and in exploiting these in resistance management strategies. Numerous overseas collaborations have included work to analyse and combat resistance problems in the USA, Israel and the Indian subcontinent. Additional research interests include studying possible side-effects of GM crops on non-target organisms, and the integration of chemical and biological control agents within Integrated Pest Management (IPM) strategies. Dr. Denholm has acted as consultant to several international projects on insect pest management and is currently serving as Secretary to the UK Insecticide Resistance Action Group (IRAG) and as Chairman of the EU-sponsored European Network for the Management of Arthropod Resistance to Insecticides and Acaricides (ENMARIA).

Sustaining the Effectiveness of Insect-Tolerant *Bt* Crops

The engineering of genes encoding insecticidal proteins from the soil bacterium *Bacillus thuringiensis* into crop plants offers numerous potential benefits to agriculture. Such crops could dramatically reduce the use of conventional broad-spectrum insecticides against insect pests, as well as remove the dependence of pest control on extrinsic factors including climate and the efficiency of traditional application methods. However, this area of biotechnology also introduces risks, especially that of pests adapting rapidly to resist genetically engineered toxins. To date, there are no substantiated reports of resistance selected directly by exposure to commercial genetically modified crops. However, resistance to conventional *Bt* sprays (selected in either the laboratory or the field) has now been reported in more than a dozen species of insect. Research into the causes and inheritance of such resistance mechanisms has provided valuable insight into the threats facing *Bt* plants, and into the likely efficacy of possible countermeasures. Tactics proposed for sustaining the effectiveness of *Bt* plants have many parallels with ones considered for managing resistance to conventional insecticides, but are more limited in scope due to the long persistence and constitutive expression of engineered toxins and the limited diversity of transgenes currently available. Indeed, for existing "single-gene" plants the only prudent and readily implementable tactic is to ensure that substantial numbers of pests survive in non-transgenic "refuges", composed either of the crop itself or of alternative host plants. In the longer-term, stacking (pyramiding) of two or more genes in the same cultivar, or possibly rotations of cultivars expressing different single toxins, are potentially more durable options for resistance management. Whatever options are adopted, however, it is essential that *Bt* plants (and their successors) are exploited as components of multi-tactic strategies rather than as a panacea for all existing pest management problems. In reality, some localized difficulties with *Bt* plants due to resistance are probably inevitable, particularly in developing countries where quality control and resistance countermeasures may prove difficult to implement. Instead of signaling the failure of this area of biotechnology, such instances should be exploited as opportunities to analyze the underlying causes, and to strengthen the resolve for deploying insect-tolerant transgenic plants on a sustainable and global basis in order to realize their considerable potential contribution to world agriculture.