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**Insecticide resistance management in Europe:
Recent developments and prospects**

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Problems with insecticide resistance in Europe have increased markedly in recent years, as a consequence of both the accumulation of resistance mechanisms by some species, and the greater diversity of pests attacking valued commodities, especially in the horticultural sector. However, there are still relatively few countries investing substantially in research to establish the extent of resistance in key pests and to formulate resistance management recommendations. IACR-Rothamsted remains one of very few institutes committed to long-term research on this subject, and with current emphasis across Europe on intensifying crop production while reducing pesticide inputs, the international relevance of its work has increased considerably. Two important features of Rothamsted's programme are its mutidisciplinary nature, encompassing population studies, toxicology, biochemistry and molecular biology, and its broad funding base. Support is provided by research councils, Government agencies, grower groups, aid organisations, and agrochemical companies both individually or collectively through their Insecticide Resistance Action Committee (IRAC). These features promote a unique integration of fundamental and practical aspects of resistance research, which is exemplified well by our long-standing work on the peach-potato aphid, *Myzus persicae* Sulzer, and the cotton or tobacco whitefly, *Bemisia tabaci* Gennadius.

*M. persicae* causes direct feeding damage on many crops, but more importantly is a major vector of several virus diseases. As a result, it has been subjected to extensive insecticide treatment and populations throughout the world have developed resistance to organophosphate (OP), carbamate and pyrethroid insecticides. Until recently only one mechanism had been identified: the overproduction of one of two closely related carboxylesterases, E4 and FE4, that degrade and sequester insecticidal esters (Devonshire and Moores, 1982). This is now



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known to reflect a progressive amplification of structural genes encoding these enzymes (Field *et al.*, 1988). Bioassays and field trials indicated that although this mechanism conferred resistance to almost all available aphicides, resistance was least expressed to carbamates including pirimicarb (eg. ffrench-Constant *et al.*, 1987). Pirimicarb has consequently assumed a key role in control strategies since it offers the best prospect of contending with high levels of carboxylesterase-based resistance late in a cropping season.

During the last few years, a new mechanism based on an insecticide-insensitive form of acetylcholinesterase (AChE), the target site of OPs and carbamates, has been identified in *M. persicae* (Moores *et al.*, 1994). This confers strong resistance very specifically to pirimicarb and to triazamate, a novel triazole aphicide that also inhibits AChE. It was first detected in a FE4-overproducing clone originating in Greece in 1990. Our work since then has documented its occurrence in Japan and a northward expansion in its European distribution (Field *et al.*, 1997). In 1996, many strains collected at sites in eastern England reporting control difficulties with pirimicarb were confirmed to possess this insensitive AChE variant. This discovery has a very profound bearing on the management of resistance in *M. persicae*. Recommendations to exploit pirimicarb to combat E4 and FE4 resistance now run the risk of accelerating the selection and spread of the new mechanism, thereby rendering this chemical ineffective over large areas. Ironically, this would also have severe repercussions for the efficacy of triazamate, one of very few novel aphicides available against *M. persicae* in Europe. Future attempts to combat resistance in this species must clearly place greater emphasis on more careful use of pirimicarb, based on detailed monitoring to document the dynamics and geographical spread of the new gene. One major objective of our work has therefore been to develop biochemical and DNA assays for diagnosing all resistance mechanisms known to occur in this species, singly or in combination (Field *et al.*, 1997).

Over the last ten years, *B. tabaci* has undergone a dramatic expansion in its geographical range and pest status. In addition to increasing in importance in the tropics and subtropics, it has spread into temperate countries including many in northern Europe. Infestations in the latter (including the UK) involve a novel biotype (the so-called 'B-type') and are associated especially with the expanding international trade in ornamental plants (Denholm *et al.*, 1996). Once introduced into protected environments, it has the potential to disrupt established IPM practices and spread onto a wide range of crops vulnerable to viruses and physiological disorders transmitted by this species. The proven capacity of *B. tabaci* to develop insecticide resistance poses another potential threat to its effective containment in Europe.

Due to the likely diverse origin of UK introductions, we have attempted to characterise the resistance status of *B. tabaci* populations from as wide a geographical range as possible. Strains from throughout the world have been tested at Rothamsted with insecticides representing the major insecticide groups to assess the extent, breadth and consistency of cross-resistance patterns. Results demonstrated the widespread, almost ubiquitous occurrence of strong resistance to OPs and pyrethroids (Cahill *et al.*, 1995). Strains collected in the UK exhibited comparable patterns of resistance to ones from the Netherlands, southern Europe and the Middle East, all possible sources of UK infestations.

Potential implications of transferring insects between countries were best exemplified by work with the insect growth regulator buprofezin. This compound was first released in the Netherlands in the late 1980s, and rapidly gained favour against glasshouse populations of whiteflies resistant to most conventional insecticides. By 1991 there were already reports of reduced control with buprofezin, and in 1992, Rothamsted was the first laboratory to confirm the occurrence of buprofezin resistance in *B. tabaci* (Cahill *et al.*, 1996). Further testing of Dutch strains showed resistance to be well established in the Netherlands, a consequence of relying excessively on a single product under environmental conditions promoting rapid population growth and buildup of resistance genes. More surpisingly, resistance to buprofezin was subsequently detected at varying frequencies in strains from UK glasshouses, prior to the official approval of buprofezin in the UK. The most likely explanation is that genes conferring buprofezin resistance had been imported into the UK from countries where this chemical was already in use.

These and other case-histories emphasise the increasing importance of international collaboration to standardise technology, exchange data, minimise duplication of effort, and co-ordinate management recommendations for Europe as a whole. Initiatives underway to harmonise approaches for assessing resistance risks and extending management guidelines within a unified EU regulatory framework reinforce the need for a European-wide perspective on resistance monitoring and management. This being so, scientists at Rothamsted and the Danish Pest Infestation Laboratory have taken the lead in preparing, funding and co-ordinating an EU-supported Concerted Action involving 13 countries and entitled "ENMARIA: European Network for the Management of Arthropod Resistance to Insecticides and Acaricides". The first ENMARIA workshop took place at Rothamsted in April 1997, when plans for sharing data and experiences, compiling a European resistance database, and organising further meetings and training visits over the next 30 months were discussed and implemented. The existence of ENMARIA will facilitate results of nationally-funded programmes being disseminated as widely and rapidly as possible across Europe. Involvement in ENMARIA is open to all interested individuals and organisations; further details are available from the main co-ordinators whose details are listed below:

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