the time taken for significant levels of resistance to become established in the treated region depends on the balance between the selective pressures exerted by the pesticides, and the amount of movement or 'gene flow' between treated and untreated regions: at high levels of gene flow, resistance takes a long time to become established; at low levels, resistance appears in a few generations; and at intermediate levels, there can even be, for quite a long time, two alternative states, one at high and the other at low levels of resistance (although this two-state regime is probably of more academic than practical interest)[5,6].

Building on these ideas, Comins[6] and others[7-9] have proposed that the time taken for resistance to appear can be significantly lengthened if fresh supplies of susceptible individuals keep appearing, each generation, in treated regions. These susceptible individuals could come from untreated refugia, deliberately set aside to conserve susceptibility, or they could (usually with more effort) be bred and released. McGaughey and Whalon refer to this as "resistance management". Other potential ways to the same end involve alternation or rotation of two or more insecticides or toxins (hoping that a significant degree of reversion to susceptibility will occur during the intervals when a particular agent is not in use), or simply using mixtures or 'stacks' of pesticides.

Intuition suggests that such methods of alternation or combination will typically result in resistance to the entire suite of insecticides or toxins evolving over much the same time-span as it would were the agents introduced seriatim. More detailed analysis of the population genetics broadly seems to support this intuition, although events can move faster or slower, depending on possible nonlinear couplings among resistance mechanisms and genes[10,11]. Gene flow from refugia, on the other hand, can greatly lengthen the time before resistance becomes a problem.

What of other options? Might it be possible to create effective refugia for susceptible pest genotypes by using seed mixtures, with toxic and toxin-free plants in the same fields? Or even to retard the evolution of resistance by arranging for some parts of the plant tissue to be toxic and others not? Mallet and Porter[4] use population-genetical models to analyse these options. Unfortunately, they find that, provided insects move from plant to plant — or, for tissue-specific toxins, from one part of a plant to another — "seed mixtures may actually hasten insect resistance compared with pure stands of toxic plants".

This perverse outcome is most likely to arise when resistance has low 'genetic dominance' — that is, when the heterozygous genotypes, RS, have fitness not much greater than susceptible ones, SS (h is small) — which is exactly the circumstance under which gene flow from spatial refugia is likely to cause resistance to evolve very slowly. In contrast to the complicated effects of pest movement among plants grown from seed mixtures, untreated regions where susceptibility is conserved have the simple effect of reducing the overall average level of selection for resistance, without altering overall dominance.

Mallet and Porter conclude that seed mixtures or tissue-specific expression of toxins may well accelerate the evolution of resistance instead of retarding it, and that on present indications toxin-free refugia look like the best bet. They speculate that legislation, rather than exhortation for cooperation, may be the answer to the attendant problems of requiring cooperation among farmers. Such legislation could, for example, take the form of an expansion of the current EC 'set-aside' programme, under which land is left fallow to maintain crop prices.

Here I have dealt largely with the biological aspects of the evolution of resistance to insecticides and toxins. Ultimately, however, the discussion must be embedded within a larger economic and social setting — as in many other bioeconomic contexts[12], short-sighted strategies of application of chemical pesticides are often rooted in real differences in economic interests between pesticide manufacturers, and farmers and society more generally[5]. We can, we must hope, learn from that lesson as well as from the new work on the evolution of resistance to transgenic crops. □

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DAEDALUS

Tactosociology

LAST week Daedalus pointed out that each region of each person's skin carries a unique and stable ecology of harmless microorganisms. Any skin contact exchanges some of these organisms; the colonists persist for some time until ultimately ousted by the better-adapted natives. DREADCO's sociologists are now using these bacteriological fingerprints of touch to study human associations.

A group of people who regularly shake hands, for example, will come to hold a group of hand-inhabiting organisms in common. A bacterial culture from someone's hand could establish whether he belonged to the group. Social groups that go in for formal kissing will soon share a characteristic facial flora. Other skin organisms could reveal the social circles of closed or preferential sexual choice. Flora that can be transferred on currency notes should neatly trace commercial clusterings. Social groupings could thus be studied quite non-intrusively, by simple bacterial sampling.

Daedalus hopes to obtain even more information by introducing test organisms into society and following their spread. A well designed, more efficient skin ecology should permanently displace the previous flora. Once launched, it would propagate by contact as a harmless 'invisible epidemic', tracing out the complex networks of human touch. Quite unrecognized by its carriers, such an epidemic might show up in the pharmacy statistics. For we are all immune to our normal skin flora; they don't infect small abrasions. But a new skin flora would briefly outwit the immune system and infect such tiny cuts, provoking the purchase of sticking-plaster or antiseptics. A 'front' of such sales, looking like a travelling wave of accident-proneness, should accompany each epidemic.

By their rate of spread, the subgroups they infect and those they pass by, DREADCO's invisible epidemics will reveal the true divisions and groupings in society. For utopian politicians, they will provide the ultimate test of the classless society — in which an invisible epidemic would spread inclusively and smoothly through the whole population. Meanwhile, Daedalus has another political use for them. At the next election, he plans covertly to infect the rival teams of political activists with mutually incompatible skin ecologies. As they furiously kiss the babies and press the flesh of their constituents, each team will propagate its own invisible epidemic into its community of influence. DREADCO will then predict the election's outcome from a bacterial sampling of voters.

David Jones