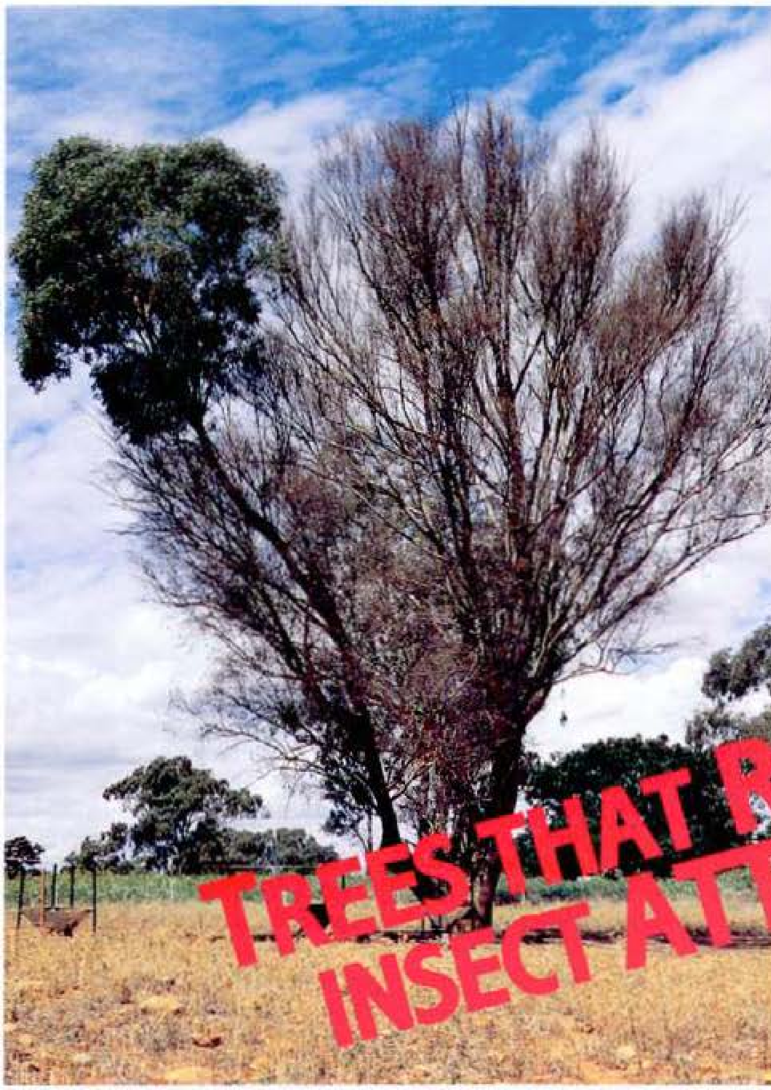
# TREES THAT RESIST INSECT ATTACK

Researchers are identifying resistant species and taking advantage of variation within species to breed resistant lines



Wolfgang Wanjura

A yellow box tree near Yeoval, N.S.W.; one branch is clearly very healthy, the rest are almost bare.

As a general rule in biology the struggle between predator and prey or parasite and host is relatively evenly matched, but sometimes the balance tips. For example, tree-clearing and the sowing of exotic pasture grasses can favour leaf-eating insects at the expense of the few remaining trees, producing 'dieback' or rural tree decline. Insects can also get the upper hand in native tree plantations, causing considerable loss of productivity.

Some eucalypts are much more susceptible than others to insect attack. About 20–30 years ago botanists noticed that some specimens of candlebark were resistant to Christmas beetles, some red gums to psyllid lerps (sap-suckers) and some red box to sawfly. The type and quantity of oils in the leaf provide at least part of the reason. It costs the plant energy to produce these, and their *raison d'être* could well be to deter insect-feeding. They may prevent feeding altogether, or they may act by costing the insect time and energy for their detoxification, thus rendering other foliage with a different chemistry a more attractive proposition.

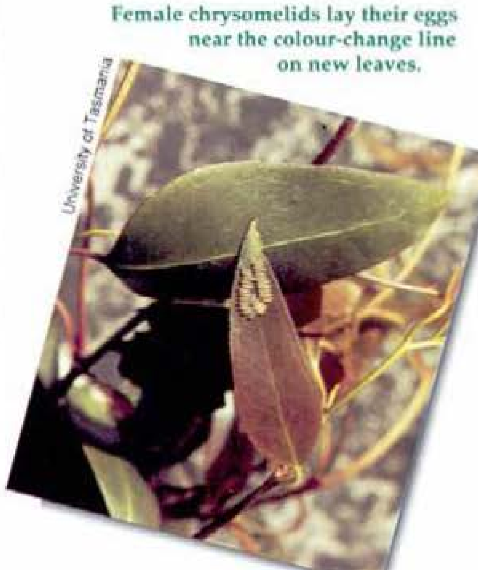
Of course, over the millennia native leaf-feeders have become well adapted to dealing with eucalypt oils. However, some trees remain relatively free from attack by some insect species because so many other kinds of eucalypt exist to provide the insects with a meal. When Australian eucalypts are planted overseas the local insects usually have a hard time feeding on them.

Dr Roger Farrow of the CSIRO Division of Entomology is detailing which trees are resistant — and to what degree — to which insects. His aim is to be able to tell farmers what species, of what provenances (tree-origins), to plant on their land in order to minimise defoliation by the particular suite of insects present. For example, in field work around Braidwood, N.S.W., he has noticed how Christmas beetles will completely defoliate manna gums (*Eucalyptus viminalis*) but not touch silver-topped ash (*E. sieberi*). Clearly, farmers in that region, who may want to plant trees for all the right land-care motives, would be well advised to choose their species wisely. Planting a line of manna gums would be wasted labour if the land were infested with Christmas beetle larvae.

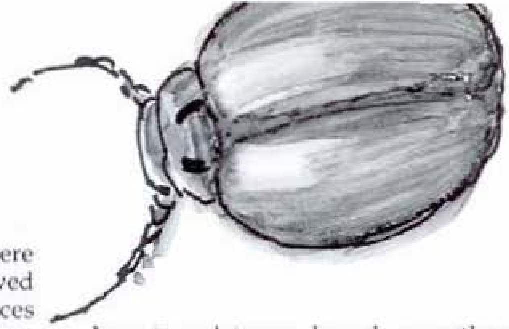
Variation also occurs between individuals of the same species; that's the basis for the natural selection of the better-adapted that drives evolutionary change. It can therefore be expected that some individual trees will be less attractive to insects than others of the same species.

Indeed, with the increased numbers of defoliating insects in many rural areas, you would expect the selection pressure on trees to increase, leading eventually to a higher proportion of

Female chrysomelids lay their eggs near the colour-change line on new leaves.



University of Tasmania



resistant individuals. In the normal course of events seedlings from slightly more-resistant trees would carry an advantage; selection would act on them and only the most resistant would thrive to produce abundant seed. Continued selection pressure over several reproductive cycles would see the emergence of fairly resistant tree populations. But, unfortunately, clearing and the presence of grazing animals mean that eucalypt seedlings in paddocks can scarcely get started — the natural reproductive cycles are all but blocked.

Do we only need to consider variation between whole trees? Mr Kevin Barker, a bee-keeper living near Yeoval in New South Wales, noticed an unusual tree near there and alerted Dr Penny Edwards and Mr Wolfgang Wanjura, of the CSIRO Division of Entomology, who were studying a Christmas beetle outbreak. What they saw was a yellow box tree (*Eucalyptus melliodora*), badly defoliated except for a conspicuous branch that remained almost completely unaffected. The scientists immediately took leaf samples from the attacked and the seemingly resistant branches. Back at the Division they fed the leaves to laboratory populations of Christmas beetles. The insects showed a particular dislike for those taken from the resistant branch.

Chemical analysis by Dr Vance Brown, also of the Division, showed major differences in oil content between susceptible and resistant leaves. Synthesis of the eucalypt oils is under genetic control — although, like most characteristics in living things, this can be affected by the environment and factors operating during the development of the individual. But, as the CSIRO scientists and Dr John Dearn of the University of Canberra point out, this example provides the first direct evidence in trees for an adaptive role for what biologists call mosaicism — that is, one part of an individual organism differing genetically from the rest of it.

Apparently, the resistant branch must have undergone a mutation when it was budding off; and so all of its developing cells carried the new genetic instruction, which resulted in a different oil content in its leaves. (Mosaicism in plants other than trees is well known to gardeners, in the form of variegated leaves.) When the scientists examined other yellow box trees nearby they found that, out of 20, 18 were uniformly resistant to attack and two were uniformly susceptible; none showed mosaicism. Biochemical differences between the 18 resistant and two susceptible trees resembled those between the resistant and susceptible branches of the mosaic tree.

Dr Edwards and her collaborators have since found other mosaic yellow box trees, with similar differences in oil composition between the branches. They have also turned up comparable within-tree variability in oil content in three other species of *Eucalyptus*.

Clearly, within-tree variation means that mutations are arising in the developing tree — not merely in the seed or the gametes that unite to form it. So, can these changes be transmitted to the offspring, or are they 'one-offs'? The scientists think they should be fully transmissible since they arise in the meristematic tissue — that is, in the growing tips — and it is this tissue that eventually gives rise to pollen and seeds.

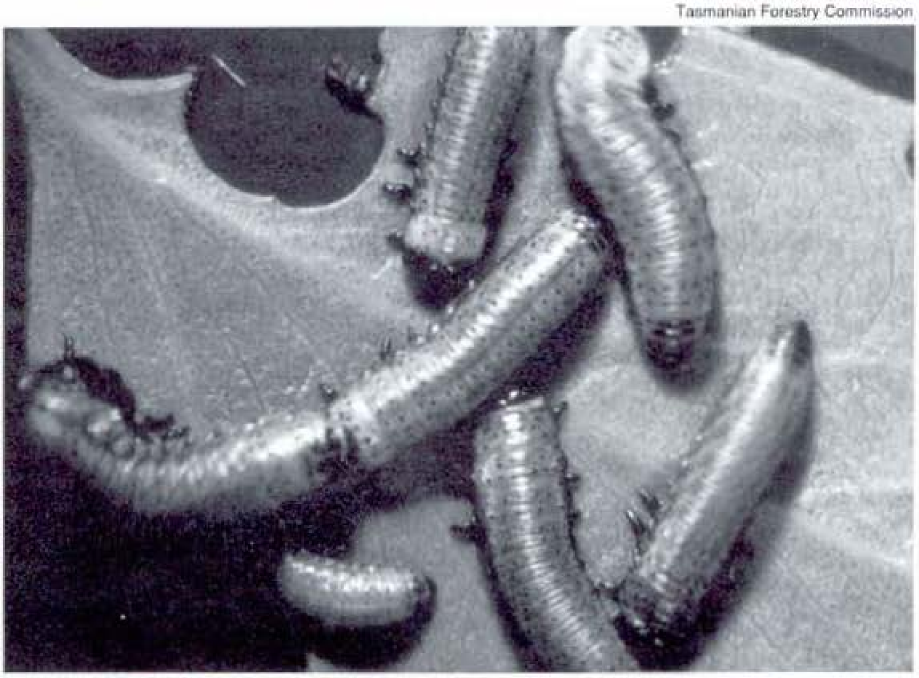
To find out, the researchers collected seed from susceptible and resistant branches and are raising it. First results, although variable, show indications that the resistance can indeed be passed on. The mutations in the developing tree seem to be a specific response to the insect activity in the susceptible trees' environment. This suggests that a selective response to environmental pressure that continues in the offspring can still operate in trees on our farmlands — although the offspring may never reach maturity if grazing is too severe.

Insect resistance based on other factors, as well as leaf oils, has been detected in plantations of mountain ash (*Eucalyptus regnans*) in Tasmania. Ms Carolyn Raymond of the CSIRO Division of Forestry is studying defoliation by the chrysomelid beetle *Chrysophtharta bimaculata*, and the trees' response. Of the many defoliators of eucalypts in Tasmania, this one is the most effective, attacking messmate stringybark, alpine ash and shining gum (*E. obliqua*, *E. delegatensis* and *E. nitens* respectively); in Tasmania, shining gum only grows in plantations. Both the larval and adult chrysomelids feed on leaves (unlike Christmas beetles, whose larvae feed underground on grass roots).

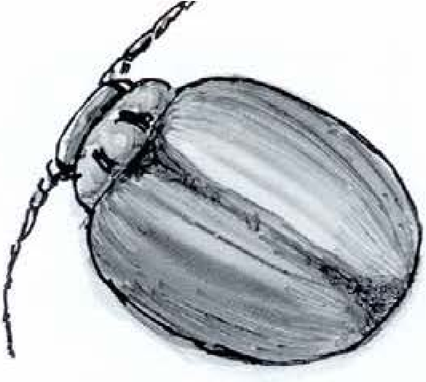
In spring, adults from the previous year emerge, having overwintered under bark. They then seek out a tree and its leaves, taking into account two important factors in their choice. Firstly, they are attracted to certain leaves, and land on them. But then they must determine the suitability of those leaves for feeding and egg-laying.

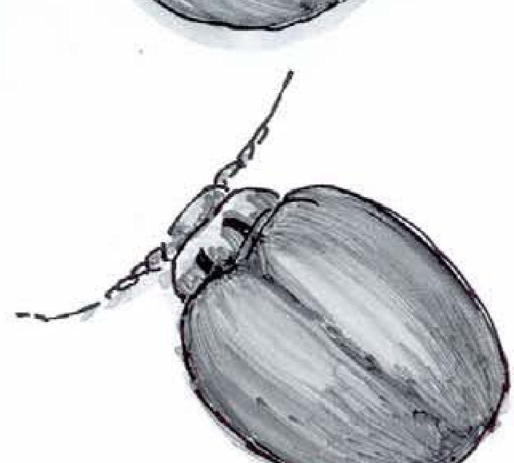
A change in leaf colour seems to be the initial attractant, as the females lay their eggs on the new leaves right by the line of contrast between the green of the leaf tip and the red of the base, shown in the photo on page 23. (As in several other eucalypts, the mountain ash spring foliage starts off being all

Tasmanian Forestry Commission



Chrysomelid beetle larvae busy feeding.





Adult *Chrysophtharta bimaculata*, one of the most effective defoliators of eucalypts in Tasmania.

red, and turns green from the tip as it matures.)

Not all leaves with the correct colour contrast will be suitable for egg-laying. Females may settle on the colour band, but refrain from egg-laying after 'sampling' the leaf, presumably because the chemical characteristics are not right. It's known that, as the colour change moves down the leaf, so changes occur both in the wax coating outside and the biochemistry within.

When the larvae emerge from the eggs they feed gregariously in colonies, removing entire leaves. Adults cause less damage, taking bites only out of leaf margins and so, unlike the larvae, do leave some functional leaf.

Currently, outbreaks of the chrysomelid beetle are either controlled by costly aerial sprays — with the risk of adverse environmental effects, such as damage to beneficial insects — or left untreated, with a consequent reduction in productivity.

Work carried out by Ms Anna Leon and Mr Dick Bashford, of the Forestry Commission of Tasmania, showed that 'light' defoliation in a stand of 5-year-old mountain ash reduced tree height by 40% compared with 'control' trees protected by spraying. These workers also found that heavy defoliation caused a staggering 90% loss of growth — meaning that the affected trees scarcely grew at all in a year. Dr David de Little of APPM Forest Products calculated that heavy defoliation of a 9-year-old stand cost about $275 per ha in lost production.

Ms Raymond has been working on a progeny trial (testing the characteristics of the offspring of a number of different mother trees) of *E. regnans*, near Burnie. She is examining 205 families from a chosen provenance, which has proved to be fast-growing and frost-tolerant. (In this sense, 'family' refers to seedlings from the same mother tree, rather than its taxonomic meaning.) In the course of the work, she noticed the existence of variation in susceptibility to the beetle's attack in trees from different families. These differences were consistent from year to year.

She is now working to identify the characteristics of the host that influence beetle behaviour, and trying to assess the degree to which the trees pass these on to their offspring. Traits with a high heritability could then be usefully included in a tree-breeding program with the aim of achieving a reasonably resistant germ line that would in the end provide a viable alternative to chemicals in the fight against the beetle.

In collaboration with Dr John Madden of the Department of Agricultural Science at the University of Tasmania, Ms Raymond has formulated a hypothesis to explain some of the observed differences in susceptibility. The two scientists suspect that resistant trees are those that produce their foliage earlier in the season, before many overwintering adults have emerged. Their young shoots have turned completely green, and thus have lost the initial attractant of the colour border, by the time the bulk of the egg-laying females are abroad.

Of course, adults may nibble at the leaf margins throughout the season, but this doesn't cause severe damage. Trees that shoot later in spring become immediate targets for egg-laying by the emerged females, as each leaf turns from red to green. These trees will suffer enormously when the larvae hatch and consume entire leaves. They may well produce a whole suite of new shoots later in the season, but will then fall victim to a completely new insect life cycle as the emergent foliage changes colour. Thus, by autumn these unfortunate trees will again have little or no foliage.

However, the early developers will. Admittedly, they will then provide food for the adult insects in preparation for the winter. Nevertheless, these trees have a decided advantage over the others, as they keep their leaves in a more or less intact state for far longer.

The scientists readily concede that they have not yet conclusively proved their idea, and hope to carry out further work. Of course, they realise that factors other than the leaf colour band are important, although this remains the initial attraction for the egg-laying females.

The importance of other leaf characteristics will be studied at the recently announced Co-operative Research Centre for temperate hardwood forestry, which will be set up in Hobart.

But is the advantage of the early-developing trees passed on to their offspring? Could it not merely be an environmental effect, connected perhaps with soil factors or temperature? Ms Raymond's initial studies suggest not. She has shown that the same trees repeat the trait season after season. And her breeding experiments have demonstrated that it is indeed strongly heritable.

In collaboration with Dr Madden and Mr Haifeng Li of the University, she has shown that attracting and non-attracting 'families' differ in their chemistry. She is now working to confirm that families that develop their leaves early usually escape the initial egg-laying phase. It seems, then, that the various components of the insect resistance are being inherited as a 'package'.

*Roger Beckmann*

**More about the topic**

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Paropsine chrysomelid attack on plantations of *Eucalyptus nitens* in Tasmania. D.W. de Little. *New Zealand Journal of Forestry Science*, 1989, **19**, 223–7.

Rural dieback: restoring a balance. R. Beckmann. *Ecos* No. 62, 1989/90, 8–15.