Oil from eucalypts

To walk in Australian native forests (especially in the summer) is to enter a fragrant world. And if you pick and crush the leaves of many eucalypts, you will be even more aware of the smell of 1,8-cineole, the major component of eucalyptus oil.

The attractive odour of cineole has ensured its use by the pharmaceutical and perfume industries. You can find eucalypt-scented washing powders, soaps, and detergents, as well as dozens of medicaments for colds and coughs.

But cineole is more than just a pretty smell. It may have a whole range of industrial applications as a non-toxic solvent — and be useful in keeping our motor vehicles running.

Although the price of crude petroleum oil has fallen in the last few years, global reserves are obviously finite, and the time will come when the supply will diminish towards nothing and, as a consequence, the price will rise enormously. In the search for alternatives, ethanol has been widely touted, and used successfully in Brazil. Car engines with minor modifications can run on a mixture containing 30% ethanol with petrol, thus reducing total oil consumption, although not of course eliminating it.

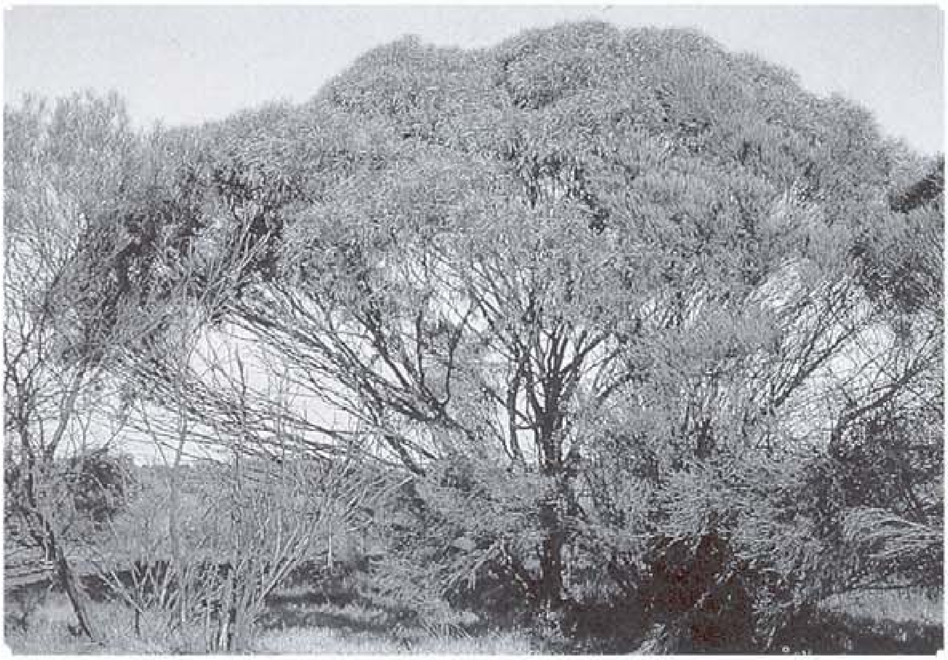
Ethanol's source is, ultimately, the sun, (as is oil's, but unlike that fuel ethanol doesn't require millions of years to form). Sugar and cellulose (itself a polymer of sugar), from plants such as sugar cane, are converted into ethanol quite easily, and as long as we have sunshine and rainfall we can continue growing the cane.

Keeping the mixture together

However, as usual, the proverbial fly lands in the ointment. The ethanol–petrol mixture doesn't remain a mixture if water is present at concentrations greater than 1%. Keeping the water out is a problem because pure ethanol is hygroscopic — it absorbs water from the atmosphere.

Producing and keeping anhydrous (dry) ethanol can be awkward, and so 'wet' ethanol is cheaper. But it's no good for motorists, because any separation of the ethanol–petrol mixture (or gasohol) will impede the working of the engine. If only something simple and non-toxic existed that could keep petrol and ethanol firmly wedded even in the presence of water! Enter the Aussie gum tree and 1,8-cineole!

Professor Allan Barton and his colleagues at the School of Mathematical and Physical Sciences at Murdoch University have shown that eucalyptus oil, if added at a concentration of 5% to a gasohol mixture, will enable the mixture to tolerate a level of water up to 3%, even at low temperatures.



The high-yielding Western Australian subspecies *E. kochii kochii*.

Eucalyptus oil can also be a fuel by itself and has a respectable octane rating. Indeed, Professor Barton and his team have achieved good performance from an experimental engine run on it. Your fragrant eucalyptus car, however, may have some problems starting when cold because of the oil's low volatility — well below that of petrol. A blend of 75% eucalytpus oil and 25% petrol seems to overcome this, according to research from Mie University in Japan.

(It's worth noting that cars using gasohol, cineole, or cineole–petrol blends produce less carbon monoxide and unpleasant hydrocarbons in their exhausts than those running on 100% petrol.)

Cineole's present cost of US$8 per litre means it is not worth using as a fuel in its own right. The leaves of high-yielding tree species contain it at a concentration, on average, of only 3%, and the highest ever recorded was 7%. Cellulose, by contrast, can account for up to 50% of some plants, and is probably the most abundant organic chemical on the planet. It would therefore be far more economic to produce ethanol as a fuel.

Fuel or fuel additive aside, cineole is, Professor Barton believes, an under-used non-aqueous industrial solvent — with the advantage of being non-toxic. Cineole, like the widely used dimethyl sulfoxide, has special solvent properties.

The world-wide consumption of eucalyptus oil is about 3000 tonnes per year. Now where does the world get the bulk of its currently rather small supplies from? Well, not from Australia! We do sell eucalyptus oil, of the highest quality, but other countries — notably Spain, India, and China — produce the largest quantities of it, and we are actually net importers. This situation is not as crazy as it seems; the reason is that harvesting the trees is very labour-intensive, and the lower labour costs in other countries put us at a disadvantage.

Our production of the oil is centred on Victoria and New South Wales, where farmers have used mallees (predominantly *Eucalyptus polybractea*) for more than a century. While the term 'mallee' includes many different species, they all share a particular growth form. They are bushy, with many stems developing from near the base. And even after nearly all their stems and leaves have been cut off, the underground lignotuber will allow regrowth. This tolerance of heavy cropping is ideal for harvesting the oil.

Many *Eucalyptus* species, however, have never been tested for their oil quantity and

Harvesting the bushy mallee (this species is *Eucalyptus polybractea*) near West Wyalong, New South Wales.

quality. So Mr Ian Brooker, of CSIRO's Division of Forestry and Forest Products Perth laboratories, teamed up with Professor Barton to test every known species in the south-west of their State.

Of course, they were looking for high-yielding oil-producers. Their job would be easier if related species had similar oil-production characteristics, which (if that were the case) could be applied in reverse — oil analysis could help in identifying related species. Mr Brooker wanted to know how reliable a taxonomic criterion this would prove to be.

In fact, he found that related species don't necessarily have related oils at all. This is also the case among those species that have been examined in the eastern States. Examples include *Eucalyptus citriodora* (the lemon-scented gum) and *E. maculata* (the spotted gum), which are closely related, similar-looking species, but have very different oils.

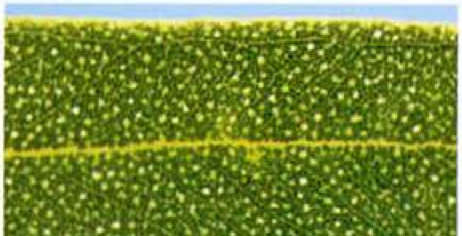
Testing trees

Two species in the Western Australian wheat belt were known to be high-yielding, although they are not currently commercial sources of oil. The scientists were interested in answering a number of questions. Would the oil be of high purity — that is, containing mainly cineole and few other components? Did the trees' oil production vary with the seasons — or the oil content of the leaves vary with the time of day? And did the two high-yielding species differ significantly?

They also wanted to establish whether any individual trees of those species were exceptionally good oil-producers, because if so they could be cloned and reproduced artificially, giving a good basis for commercial production.

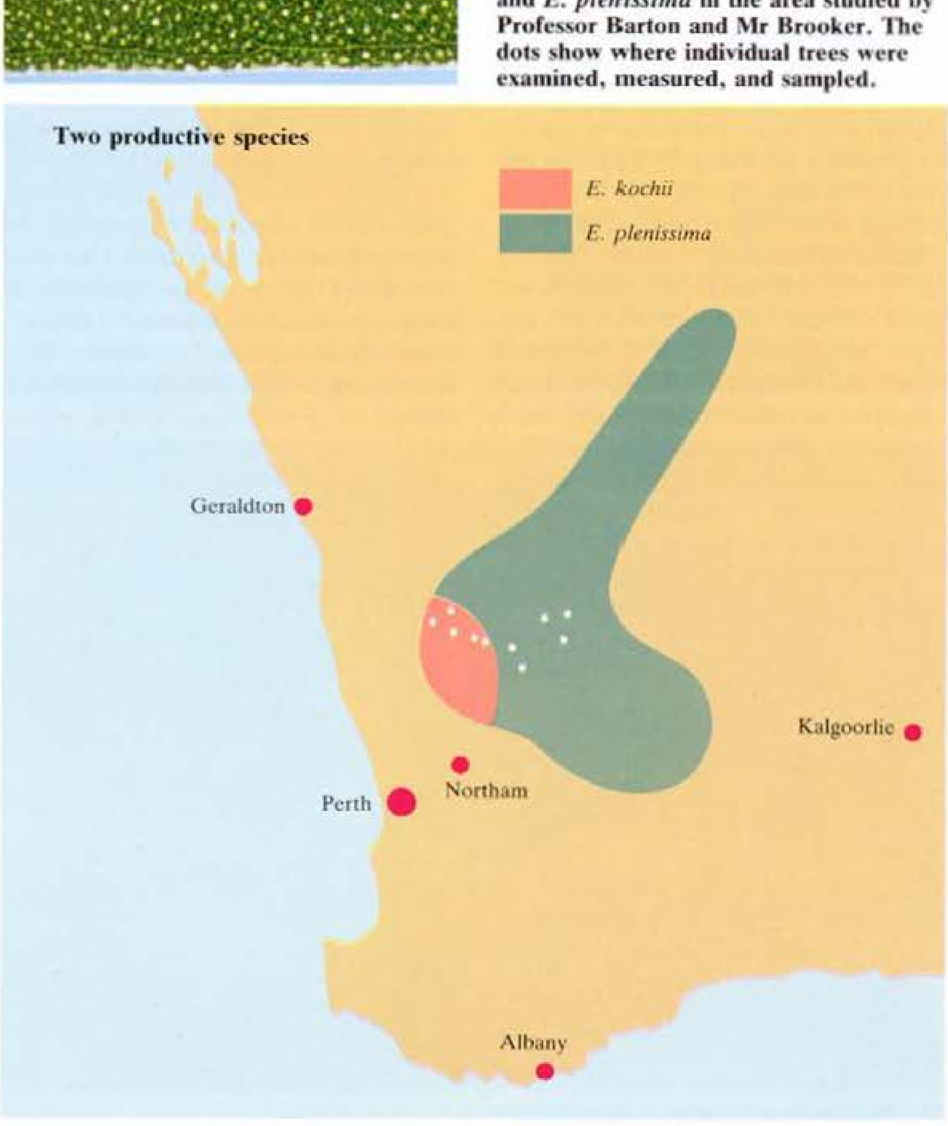
The two species — *Eucalyptus kochii* and *E. plenissima* — are both mallees with that characteristic growth form. Their distribution now is patchy, as they occur in the State's wheat belt where so much native vegetation has been cleared.

(An interesting spin-off from this work was a discovery about the taxonomic status of the two eucalypts. During the course of field work, Mr Brooker recorded various characteristics of the trees' leaf and fruit shapes — or morphology as biologists say — to find any possible association between these and oil production. As expected, there was none, but analysis of the differences in morphology of fruit and foliage



***Left*: A leaf from a high-oil-producing *Eucalyptus kochii* tree. The oil glands are the small translucent circles, easily visible with the naked eye in a leaf held up to the light. Leaves of most species would have fewer glands than this.**

***Below*: Distribution of *Eucalyptus kochii* and *E. plenissima* in the area studied by Professor Barton and Mr Brooker. The dots show where individual trees were examined, measured, and sampled.**



More good oil

Eucalypts are not the only Australian native plants to yield a good oil. Tea-tree oil — from *Melaleuca alternifolia*, whence comes its other name of 'oil of melaleuca' — has long had a reputation as a useful antiseptic substance. Back in the 1920s it was found to have an antibacterial action ten times stronger than that of the popular phenol, which burns and stings mercilessly when applied to any wound. Tea-tree oil, happily, does not.

This fact — that it doesn't damage any tissue, and hence will not cause inflammation or pain — makes the oil particularly attractive as an effective substance against bacteria and fungi, because we can use it not only on broken skin, but also on the body's unprotected mucous membranes, such as the mouth and vagina.

The bulk of the oil comes from the coastal region of northern New South Wales, where wet warm weather allows the tea-tree to grow well and give its highest yield. (It will grow elsewhere, but is less productive.) As with eucalyptus, the oil is extracted by distillation from the leaves — a process that has been in existence for most of this century. Despite this and the fact that medicinal applications are well established, the industry has not prospered because the supply of the oil — and its quality — could not always be guaranteed. Indeed, only recently have samples from different trees been chemically analysed and compared.

Dr Lyall Williams and Ms Vicki Home, of the School of Chemistry at Macquarie University, have discovered that the oil can show considerable variation in the proportions of its major constituents, even when coming from almost identical trees. For example, the compound terpinene-4-ol, which scientists 60 years ago demonstrated was its major antibacterial component, can vary from 30 to 50% of the total.

And in complete contrast to eucalyptus, where cineole is a prized component, tea-tree oil contains only 4 to 10% — indeed the Australian standard requires it to have a concentration less than 15%. The reason is that cineole is a skin irritant, causing dilatation of the capillaries and inflammation, and so will hurt an open wound. In fact, many creams that 'heat' the skin contain it.

Obviously, the best-quality oils will be low in cineole and fairly high in terpinene-4-ol. (Incidentally, the latter is not entirely responsible for all the antimicrobial action, as the whole oil kills microscopic nasties more effectively than any of its individual constituents.)

One aim of the work at Macquarie is to help the Australian tea-tree oil 'cottage' industry develop its full potential. Until recently the industry, which supplied almost the entire world market of 50–60 tonnes per year, depended on lone 'bush-cutters' rather than plantations.

Dr Williams is analysing oil samples from many different carefully numbered trees, in order to establish those that produce the highest-quality oil in the greatest amounts. He can then give the data to the farmers and plant breeders, so that they can start a selection program that will result in an increased per-hectare yield of the best type of oil, and a guaranteed consistency of the product year after year — which currently does not exist.

It is this lack at present that discourages large companies from using tea-tree oil in widely sold formulations. Once growers achieve guaranteed consistency and increased efficiency of production, Dr Williams believes that the global market for the oil will enlarge enormously. Other countries have also realised this, and trial plots of tea-trees are already established in China and California.

Several reasons account for the sudden interest in this homely bush remedy. Many antibiotics can cause unwelcome side-effects, and anyway are becoming less effective as bacteria develop resistance to them. A resurgence of interest in what are thought to be 'natural' remedies is also under way and, now that the existence of plantations guarantees at least some continuity of supply, interested businesses are able to make use of this one. Finally, it is quite likely that the oil causes fewer adverse reactions than many commonly used substances. So, all of us should soon be well oiled!

A Holden V-8 test engine running on a fuel blend containing eucalyptus oil; its performance and emission rates are being monitored.

was not entirely in vain, as it enabled Mr Brooker to propose that the two species were in fact merely two subspecies, thus making them more closely related than had been thought.)

To carry out their experiments the scientists chose 10 sites, with the number of trees ranging from 3 to 11 per site. They sampled all the trees every month for 2 years. Each sample comprised 4 g of fresh leaves of a similar age. Some were taken in the morning and some in the afternoon, in order to test for oil variation during the course of a day. Other samples were collected at different points around the crown to see whether the position of the leaves on the tree made any difference.

It may soon be profitable for farmers to harvest eucalyptus oil as a side-line.

Back in the laboratory, the Murdoch University team measured the cineole content of all the samples using the technique of gas chromatography. They also determined the water content, which meant that they could then express cineole concentration per dry weight of leaf.

Sure enough, they confirmed that the two tree types had at least 90% of their leaf oil in the form of cineole in most of the specimens. In terms of production, this would give figures higher than the average harvest yield of *Eucalyptus polybractea* in Victoria.

Analysis of the data about oil concentrations showed that the positions of the leaves in the crown, and the time of day they were picked, had no evident effect. A small seasonal variation did exist, with highest oil production occurring in the summer, and figures for the quantity of oil did differ slightly between the 2 years of the study. On the whole, though, the time of harvest of your fragrant oil crop should not matter greatly.

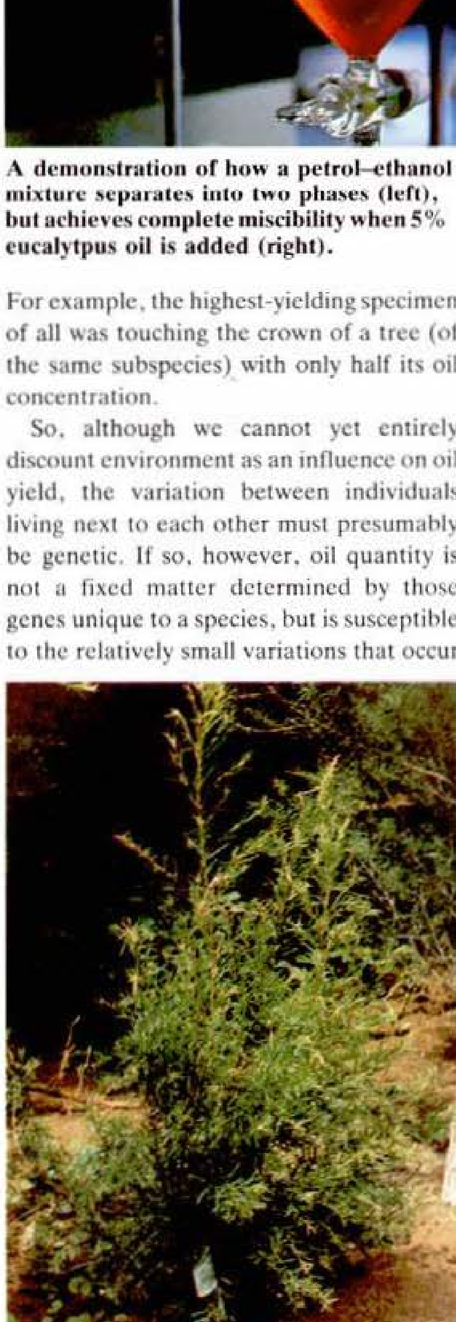
Individualists

But the most important finding was the large variation between individual trees within the one subspecies. In other words, the mere fact that the eucalypt growing in your garden is a known high-yielding species does not necessarily mean that it will produce a great quantity of oil. A species can vary widely throughout its range. The scientists found significant differences even between adjacent trees.

A demonstration of how a petrol–ethanol mixture separates into two phases (left), but achieves complete miscibility when 5% eucalytpus oil is added (right).

For example, the highest-yielding specimen of all was touching the crown of a tree (of the same subspecies) with only half its oil concentration.

So, although we cannot yet entirely discount environment as an influence on oil yield, the variation between individuals living next to each other must presumably be genetic. If so, however, oil quantity is not a fixed matter determined by those genes unique to a species, but is susceptible to the relatively small variations that occur between the genomes of individuals within one species.



Melaleuca alternifolia **showing 2 months' regrowth after cutting for extraction of tea-tree oil.**

The scientists are continuing detailed analyses of other species in the area to find further possible sources of high-purity oil. They believe that it will soon be profitable for farmers to harvest eucalyptus oil as a side-line. If they can find good producers that are also salt-tolerant, then agroforestry using these would be a very real possibility in areas with salinity problems.

One final point: some of Australia's most famous and beautiful eucalypts are at the bottom of the league when it comes to oil. The West's tall karri and hardwood jarrah, and Queensland's tropical eucalypts, are poor producers, as are such desert trees as the 'ghost gum'. It seems that the species living away from the coast in areas of intermediate rainfall are the best.

As to why they make the oil, we have no sure answer. One obvious possibility is to protect their leaves from being eaten; but this advantage is countered by the clear disadvantage that the oils make the trees far more combustible.

Roger Beckmann

More about the topic

The cineole content and taxonomy of *Eucalyptus kochii* Maiden and Blakely and *E. plenissima* (Gardner) Brooker, with an appendix establishing these two taxa as subspecies. M.I.H. Brooker, A.F.M. Barton, B.A. Rockel, and J. Tjandra. *Australian Journal of Botany*, 1988, **36** (in press).

Eucalyptus oil as a component of petrol–ethanol fuel blends. D.G. Ammon, A.F.M. Barton, and D.A. Clarke. *Search*, 1986,**17**,92–5.