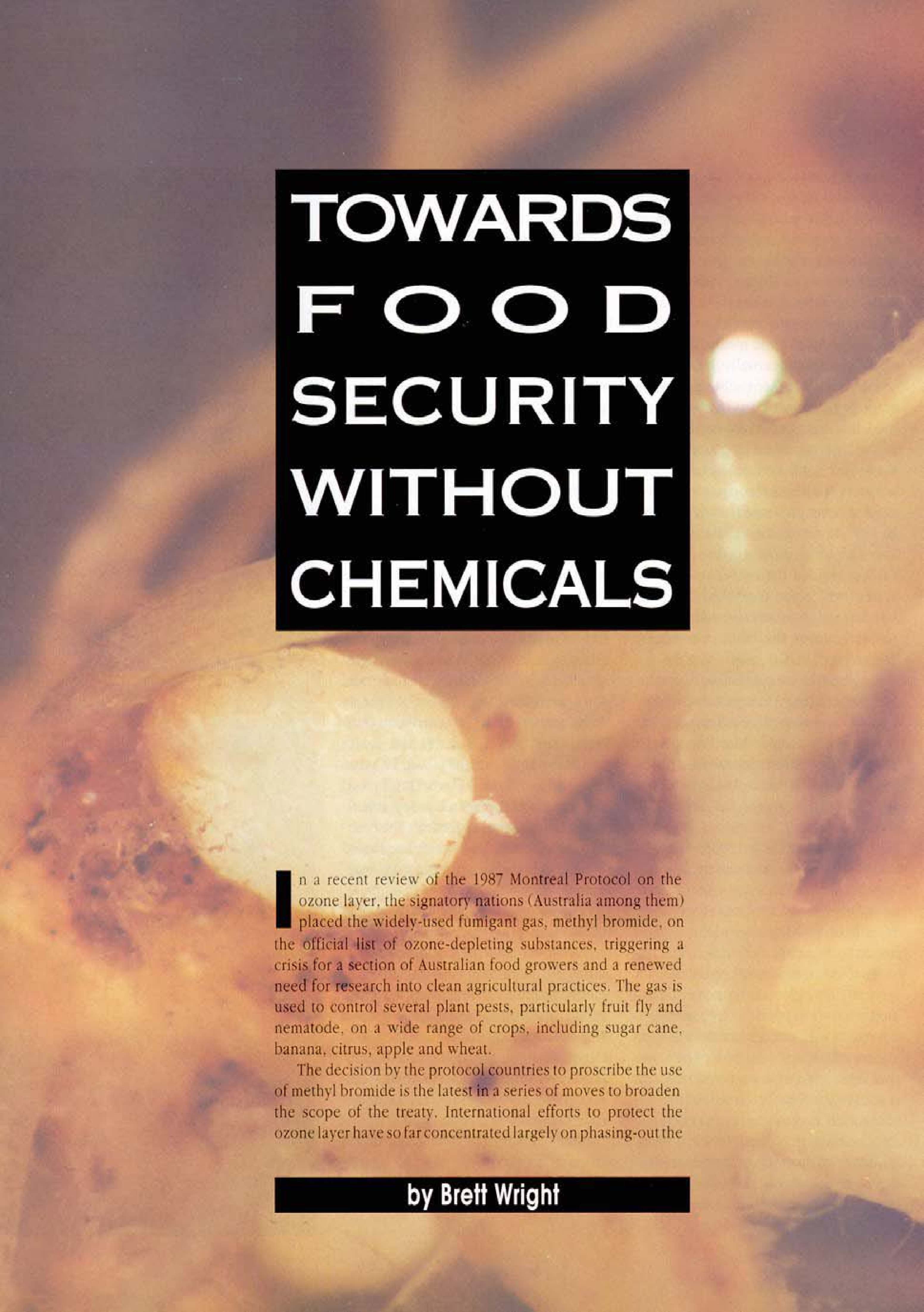


TOWARDS FOOD SECURITY WITHOUT CHEMICALS

In a recent review of the 1987 Montreal Protocol on the ozone layer, the signatory nations (Australia among them) placed the widely-used fumigant gas, methyl bromide, on the official list of ozone-depleting substances, triggering a crisis for a section of Australian food growers and a renewed need for research into clean agricultural practices. The gas is used to control several plant pests, particularly fruit fly and nematode, on a wide range of crops, including sugar cane, banana, citrus, apple and wheat.

The decision by the protocol countries to proscribe the use of methyl bromide is the latest in a series of moves to broaden the scope of the treaty. International efforts to protect the ozone layer have so far concentrated largely on phasing-out the

by Brett Wright

production and use of chlorofluorocarbons (CFCs) and halons, but greater attention is now being paid to a wide range of organic compounds that contain hydrogen and either of the halogens, chlorine or bromine. These include the hydrochlorofluorocarbons (HCFCs), methyl chloroform, perchloroethylene, trichloroethylene and methyl bromide.

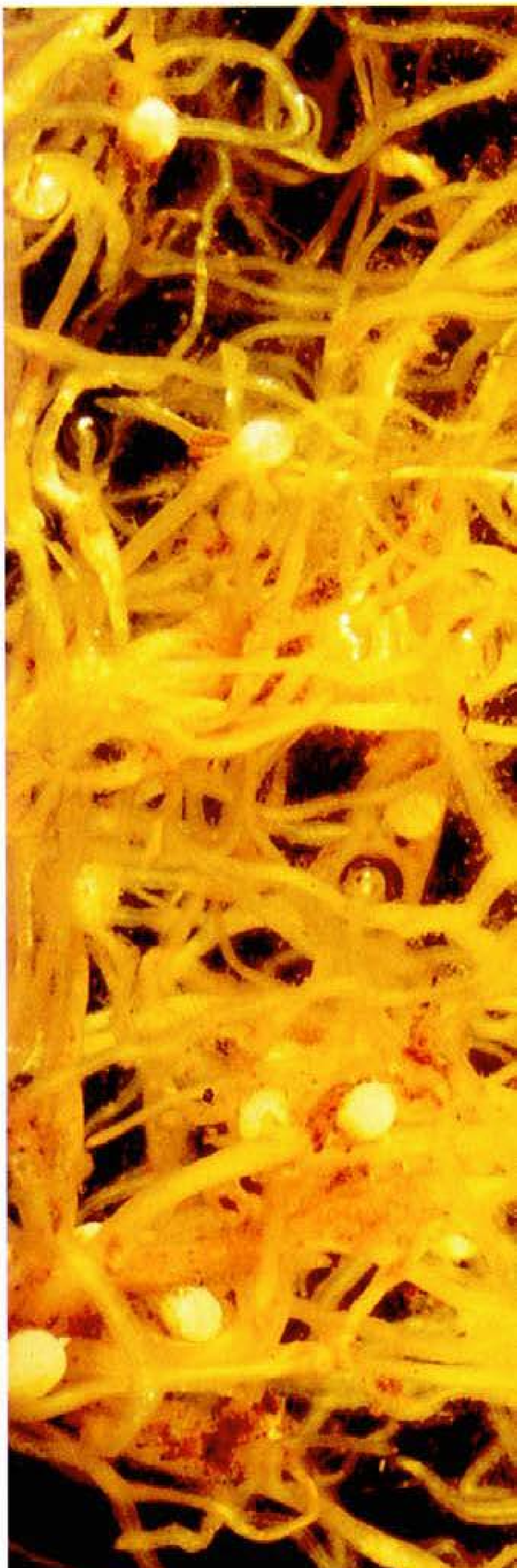
While such 'partially halogenated substances' (so-called to distinguish them from the halons which are fully halogenated, that is, no hydrogen) do not persist in the atmosphere as long as the CFCs, some are produced in large enough amounts by chemical companies to have a significant impact on stratospheric ozone. In 1990, in recognition of this problem, the signatory nations of the Montreal Protocol added the HCFCs and methyl chloroform to the controlled list. (Carbon tetrachloride was also added at that time.) Then at the latest meeting, in Copenhagen in November 1992, the parties agreed to include methyl bromide (CH_3Br), a highly toxic gas chiefly used as a soil and post-harvest fumigant. The meeting recommended freezing the use of the fumigant at current levels, with the possibility of further restrictions following the next review of the protocol in two years time.

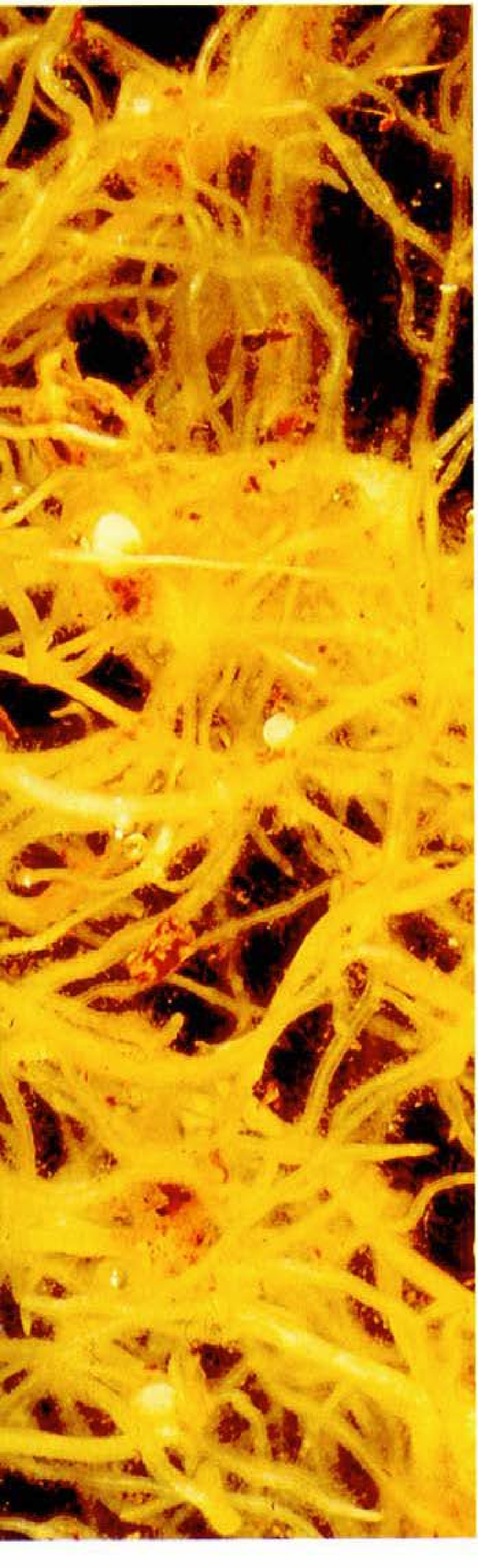
Global use of methyl bromide is estimated at 65 000 tonnes annually. Australia imports about 800 tonnes a year, mainly from Israel, most of it for the fumigation of soil to protect crop plants against attack by wormlike nematodes. The rest is used in the making of chemicals, for general fumigation, and increasingly as a post-harvest insecticide for fruit and vegies to replace ethylene dibromide, a suspect carcinogen banned in the United States and Japan, and now declining in use in Australia and New Zealand. (Methyl bromide itself may also cause cancer — a Dutch study published in 1984 found evidence of stomach cancer in rats exposed to the chemical, but subsequent research has not confirmed the results.) It is estimated that about half of the methyl bromide used escapes into the atmosphere.

The immediate elimination of methyl-bromide use in Australia would be hard to achieve and could ruin some producers in industries where alternatives are not readily available. However, atmospheric emissions could be cut substantially by a variety of means, including reduced dosages and better-sealing tarpaulins in soil fumigation work, a greater use of alternative chemicals, biological control methods, crop rotation, and the development of plant varieties resistant to nematodes and other pests.

Some of these measures (such as biological control) are hampered by a lack of relevant biological research. For example, Australia's nematode fauna is unique and largely unstudied, despite an estimated loss to Australian agriculture of $300–450 million annually due to plant-parasitic nematodes. A senior Australian nematologist, Dr Graham Stirling, from the Queensland Department of Primary Industries, recently claimed that Australia and New Zealand had fewer nematologists than they had 10 years ago, and that those still working 'lacked the backing of a research group able to take a fundamental approach'. The problem, he claimed, had been exacerbated by research bodies reducing their commitment to plant nematology.

Nevertheless, research is in train in CSIRO and other agencies directed at reducing our need for dangerous or polluting agricultural chemicals, including methyl bromide. In one recent development, researchers from the Victorian Department of Agriculture and the CSIRO Division of Plant Industry have discovered a new source of plant genes that can render wheat resistant to cereal cyst nematode (*Heterodera avenae* Woll.), one of the most damaging pests affecting cereal crops in southern Australia. In another development, scientists at the CSIRO Divisions of Horticulture and Food Processing





A female cereal cyst nematode feeding on the roots of a wheat plant. Its body is distended with several hundred eggs which will remain dormant until hatching in autumn, coinciding with the sowing of cereal crops.

and the New South Wales Department of Agriculture have successfully tested several non-chemical methods for killing Queensland fruit fly (*Bactrocera tryoni*) in a range of fruits, including cherries, oranges, lemons and melons.

In the nematode research, a search through germplasm collections maintained in Tamworth and Canberra uncovered a wild plant commonly known as goat grass (*Triticum tauschii*), a plant native to the Pahlavi region of Iran, and one of the evolutionary precursors of modern wheat. Screening tests by the Victorian Department of Agriculture in Horsham and the CSIRO Division of Plant Industry in Canberra found that several varieties of *T. tauschii* are highly resistant to cereal cyst nematode, a worm that invades the root tips of a plant and retards root growth. Later work established that when *T. tauschii* was crossed with a wheat variety the hybrid plant also displayed a high level of resistance to nematode attack.

Farmers once combatted cereal cyst nematode with ethylene dibromide, but chemical use has declined in favour of crop rotations. By growing crops or pastures which do not host the nematode for two successive seasons, between susceptible cereal crops, nematode populations are kept at low levels. In the 'off-years', farmers typically grow grain or pasture legumes, rapeseed or resistant cereal varieties. While crop rotation has worked well in many areas, the disease is still estimated to cost farmers $30–70 million a year, and there remains the danger that new types of disease-causing nematodes will develop. At present, it is thought just one particular type of the nematode, *H. avenae*, causes disease in cereal crops in Australia — but overseas 10 types have been identified, suggesting that *H. avenae* can vary its attack on cereals and become more aggressive.

Furthermore, resistance to the disease in Australian wheat is very narrow. The handful of Australian wheat varieties currently resistant to cereal cyst nematode apparently all derive their resistance from a single gene. Scientists fear genetic selection in nematode populations could overwhelm the effectiveness of that gene, and lead to a rapid upsurge in the virulence of the disease.

The research underway in Horsham offers a ray of hope for the development of more secure resistance to cereal cyst nematode. Mr Russell Eastwood, at the Victorian Institute of Dryland Agriculture, says the resistance found in *T. tauschii* occurs in a section of DNA known as the 'D genome'. Not only is this thought to be the first time resistance has been found in the D genome (thereby representing an opportunity for a new source of resistant genes), but the same genome also occurs in bread wheat.

'That makes it relatively easy to cross *T. tauschii* into wheat', Mr Eastwood said. The researchers were able to cross *T. tauschii* with a durum wheat variety known as Langdon. Crossing the two varieties introduces a resistance gene into the hybrid wheat. In a trial using nematode-contaminated soil, Langdon was found to be a susceptible wheat variety, averaging nearly 30 female nematodes per plant on the roots. In contrast, in the same trial, the roots of Langdon- *tauschii* hybrid plants were found to have no female nematodes at all.

According to Mr Eastwood, 'the level of resistance is high, although at this stage we don't know if *tauschii* is resistant to the other types of cereal cyst nematode.' He also said that, despite the success of crop rotation, there remains a need to develop new varieties resistant to cereal cyst nematode. 'In the Mallee, for example, it's more difficult to use crop rotations because they can't grow a

The cereal cyst nematode spends the summer in brown cyst, each containing up to 400 nematodes, waiting to attack the newly planted cereal crop.

Goat grass *(Triticum tauschii)* is a native of Iran and a precursor of modern wheat. Scientists are using it to introduce resistance to cereal cyst nematode in Australian wheat cultivars.

Cereal cyst nematode causes abnormal root growth in cereal crops. This leads to nutrient and water stress — seen as a yellowing in crops. The cost to Australian cereal farmers is estimated to be $70 million annually.

lot of the legume and oilseed crops that are resistant.' He warned, however, it could take a further six years or longer to develop the *tauschii* discovery into a commercially-available wheat variety.

Methyl bromide is also used in horticulture to control a variety of pests and, although consumption is small compared with broad-acre soil fumigation, the chemical is critically important for growers striving to meet the stringent pest control standards imposed on the export of fruit and vegetables. For example, fruit exported to the United States must be treated to a standard that permits the survival of no more than one live fruit fly for every 100 000 insects treated.

... methyl bromide is a dangerous but highly effective agent for the elimination of the Queensland fruit fly ...

As a post-harvest disinfestant, methyl bromide is a dangerous but highly effective agent for the elimination of the Queensland fruit fly, a serious pest of all fruit and most fleshy vegetables grown on the east coast of Australia (with the exception of eastern Tasmania). The fly (*Bactrocera tryoni*) is a rapacious pest in coastal orchards and is now showing signs of adapting to inland conditions.

Finding acceptable, non-chemical alternatives to methyl bromide in horticulture will not be easy but at least one method is showing promise. Researchers at the CSIRO Division of Horticulture and the New South Wales Department of Agriculture in Narara, NSW, have successfully tested a method for disinfesting cherries, oranges, lemons and melons which depends on little more than a careful application of hot water.

In an experiment using Eureka lemons, Dr Murray Brown and Dr Rupinder Pannu at the Division's Sydney laboratory immersed the fruit in hot water until the flesh at the centre of each lemon reached 46°C, and then held at that temperature for 24 minutes. Such conditions are known to destroy the eggs of Queensland fruit fly immersed in hot water.

Of course, treating lemons in this manner affects the quality of the fruit — the trick is to achieve the right amount of heating without signficantly reducing weight, firmness, skin colour and taste.

Fortunately, the outcomes were favourable. Weight loss in the treated lemons was greater than in a batch of untreated lemons, but the difference was less than 10% after three weeks of storage. Skin greenness and firmness also declined more rapidly in the heat-treated lemons than in the control lemons. However, the scientists found that by pre-treating the lemons (storing them at 38°C for 15 hours prior to immersion) the decline could be reduced considerably.

To evaluate sensory acceptance, the researchers employed a panel of tasters. Comparing the heat-treated with the control fruit, the panel found no significant change in skin or flesh quality or in the colour, odour and flavour of the extracted juices. Overall, Dr Brown felt the results showed that hot-water immersion has 'high potential' as a non-chemical method of disinfestation.

Follow-up work in collaboration with Andrew Jessup at the Narara Post-harvest Laboratory has confirmed that view and demonstrated the effectiveness of hot-water immersion and hot-air treatment in killing Queensland fruit fly.

In a recent yet-to-be-published experiment using cherries, the researchers subjected egg-infested fruit to a variety of time-temperature conditions. The eggs in two cherry varieties — Ron's Seedling and American Bing — were found to suffer 99·99683% mortality (that is 32 survivors per million insects) when the fruit centres were held at temperatures of 48·3 and 46·9°C respectively for a period of 10 minutes. That is sufficient to meet the stiff fruit-fly limits for export of fresh produce to the US and Japan.

Extensive evaluation of fruit quality confirmed the earlier work: heat treatment of cherries causes a small drop in quality, but the fruit remained at a highly marketable standard. Related research also indicates that some peach varieties can be heat-treated. Avocadoes, however, did not respond well.

The scientists are continuing their research with peaches, grapes and apples to better understand how these fruits respond to the heat disinfestation of not only fruit fly, but light brown apple moth and codling moth, two other serious horticultural pests. They are also developing equipment capable of heat-treating fruit in large batches.

While success in these fields of research is unlikely to lead to complete independence from agricultural chemicals, such as methyl bromide, which are hazardous to health or the environment, a substantial or even drastic reduction in chemical use looks highly possible.

Towards food security

Adding disease-resistance genes to wheat. *Rural Research* 151, Winter 1991, 13–16.

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Postharvest disinfestation of Eureka lemons by hot water immersion. Murray A. Brown and Rupinder Pannu. Paper presented at meeting of *Australian Society of Plant Physiologists*, Sept. 1992, at La Trobe University, Victoria.