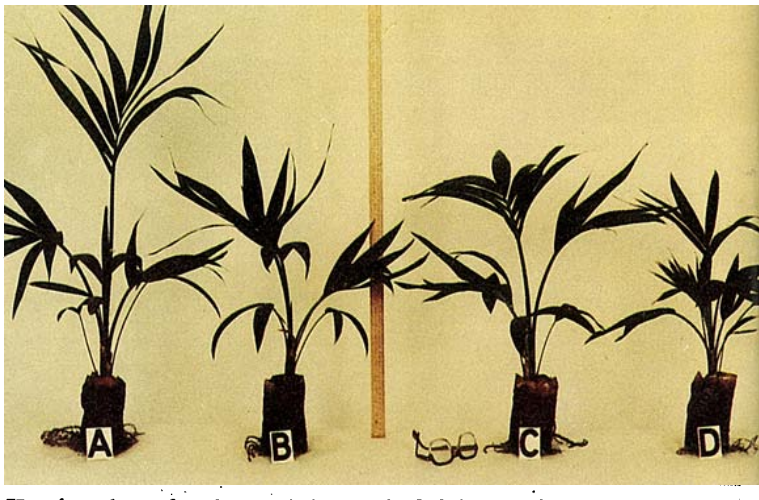


Kentia palms after 9 months' growth. Minimum air temperatures were 18°C for plants A and B and 12°C for plants C and D. Palms A and C had their roots warmed to 25°C.

Root-warming saves energy

Greenhouse cultivation is a rapidly growing industry in Australia. Over the past few years, sales of ornamental plants raised in greenhouses have increased by about 30% a year. The industry has flourished despite an approximately sixfold increase in heating costs since 1972.

Winter nights in southern Australia are cold, and growers need to provide a lot of heating to maintain the equable conditions that protected crops require. The latest estimates put the industry's heating bill at around $60 000–$100 000 per hectare of greenhouse per year.

Naturally, there is a great deal of interest in reducing energy costs. Scientists at the CSIRO Centre for Irrigation Research at Griffith, N.S.W., have shown that changes to greenhouse design can result in big energy savings (see *Ecos* 31). More recently, they have demonstrated another way to make big cuts in energy costs — warming the roots of the growing crops. The savings result from the fact that, in some cases, root-warming reduces the amount of air-warming needed.

Roots normally have about the same temperature as the surrounding soil, and if the soil gets too cold they have difficulty absorbing nutrients and so the plants do not grow well.

Warming the roots not only ensures that these remain warm enough to function properly, it can also have additional marked effects on plant growth in some species that have the growing point close to the soil surface. For such plants, as long as the roots are kept at the optimum temperature for the species, air temperatures can be reduced by several degrees and, under these conditions, growth and yields may increase well above expectation.

Tomatoes growing in rockwool and nourished by a warmed nutrient solution circulated in pipes.

Roses growing in a root-temperature experiment.

Root-warming is not a new concept. In Britain, scientists have conducted many experiments with root-warming and lowered night-time air temperatures in tomato crops. However, the technique results in later fruit maturation and in

Europe, where market conditions demand early cropping for economic viability, this has proved a distinct disadvantage.

Southern Australia has quite different market conditions and climate. Here, greenhouse tomatoes fill the gap between the northern winter and the southern summer crops and are grown at a time of high light intensity, warm days, and cool to frosty nights. To investigate the feasibility of root-warming under these conditions, Dr Gerald Moss has been conducting experiments with tomatoes and a range of other greenhouse crops at Griffith.

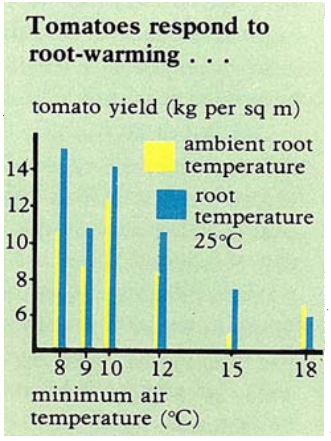
He grew the plants hydroponically (without soil) by a proved system known as the nutrient film technique. In this method, the plants grow in plastic troughs containing a thin film of nutrient solution that is continuously recycled — a boon to root-warming technologists because the nutrient solution can be heated at little expense in a central tank.

Growing plants in rockwool, an inert material composed of mineral fibres, is another recent innovation. The rockwool 'bats' are wrapped in plastic, placed on polystyrene foam, and irrigated frequently with a nutrient solution. Root-warming can be achieved by passing warm water through plastic pipes in the foam base.

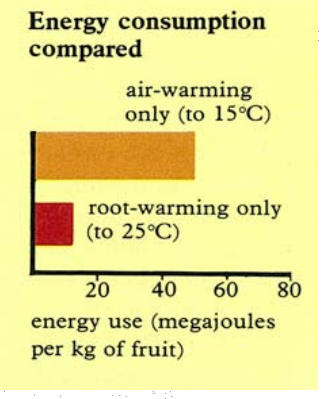
Plants grown more conventionally, in pots of soil, may be similarly heated by circulating warm water through pipes in the supporting benches or floor.

Tomatoes

In one set of experiments on growth and yields, Dr Moss compared hydroponically grown tomatoes cultivated without root-warming



Rouge de Marmande tomato plants with root-zone warming to 25°C usually yielded more fruit, from 8 weeks of picking, than those at ambient temperatures.



Energy consumption per kg of tomatoes produced fell by 77% when root-warming was applied rather than air-warming.

against others cultivated with a minimum root-zone temperature of 25°C. He set night-time air temperatures at 15°C, 10°C, or 8°C in one experiment and 18°C, 12°C, or 9°C in a second. The minimum daytime temperature was set at 21°C, with automatic venting of the greenhouse at 25°C.

After 8 weeks of harvesting, the cultivar Rouge de Marmande produced considerably higher tomato yields with root-warming than without it — averaging 13–16% more. Another piece of good news is that the lower night-time air temperatures resulted in the best yields. The trials show that, in southern Australia, growers may produce greenhouse tomatoes through the winter with practically no air heating (except to prevent frost), as long as they warm the roots. Very large energy savings are possible.

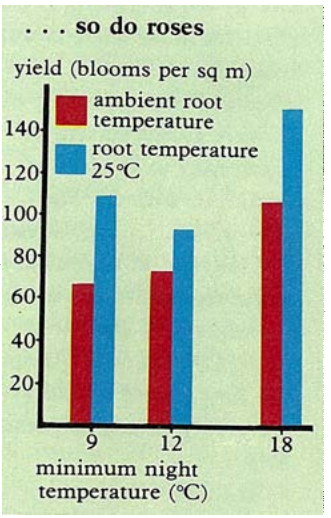
Mr Keith Garzoli, an engineer at the Centre, has used a computer model to calculate that greenhouse energy consumption with root-zone warming (to 25°C) was only about 32% of that required to maintain a minimum air temperature of 15°C — an oft-quoted requirement for indirectly maintaining satisfactory soil temperatures in conventional greenhouse systems. Taking into account the higher yields with root-warming, he calculated a reduction of some 77% in energy consumption per kg of fruit.

The better yield in root-warmed Rouge de Marmande was due to an increase in the number of tomatoes harvested per plant, without loss of fruit size. However, other results indicated that Sonato, a European greenhouse tomato, does not respond as well to hydroponic root-warming, so cultivars will need to be carefully selected for commercial enterprise.

The only apparent disadvantage of growing tomatoes with lower night temperatures was the delay in commencement of fruit-picking by 4–5 weeks. But this should not cause problems in Australia, because there is no reason why the crop could not be planted earlier.

Ornamental palms

With indoor plants becoming increasingly popular, ornamental Kentia palms command a growing market. Few modern offices are without one, and Australia now exports them in large quantities. Their propagation in greenhouses



A raised root temperature resulted in more blooms when 'Sonia' roses were grown in the greenhouse from May to October.

has required large amounts of energy, because they require warm conditions over a considerable period of time.

Dr Moss grew palms from seedlings, and compared the growth of some with the root zone heated to 25°C with that of others with no root-warming. Plants were subjected to minimum night-time air temperatures of 18, 12, and 9°C. Root-warming increased growth by 31% and leaf area by 32%, on average. Palms grown at the lower night temperatures but with warmed roots grew as much over the 9 months as those experiencing mild night temperatures of 18°C with no root-warming.

The results show that, by using a root-zone warming system or a warm-floor system, growers of ornamental palms could achieve considerable energy savings because they could reduce air temperatures drastically with little effect on growth. Alternatively, they could achieve a faster turnover of plants for the same amount of energy.

Roses

Another important greenhouse crop with large

energy requirements is the rose. Dr Moss used 'Sonia' roses in his study of the effects of root-warming on flowers grown in winter (from May to October). Again, he found a big potential for energy savings.

The yield at the lowest night temperature with root-warming was similar to that at 18°C without it. Adopting the first course would give an energy saving of some 80%.

At the 18°C night temperature, root-warming increased the number of blooms produced by 42% and gave blooms with longer stems. The energy saving per bloom produced was about 30%. Despite the larger savings possible with lower night temperatures, Dr Moss thinks growers may prefer to use the combination of 18°C plus root-warming because of the higher yields and more consistent production it offers.

Being both simple and cheap, root-zone warming is finding commercial application overseas — particularly in hydroponic systems. Such systems are ideally suited to it. As the warming water needs to be at only 25–40°C, solar collectors could readily supply the heat needed. The root-warming system at Griffith will eventually incorporate solar heating.

Numerous crops — including cut flowers, tropical foliage plants, strawberries, nursery stock, and lettuces — are cultivated in greenhouses, and Dr Moss is continuing research into energy savings and the effects of root-warming in several species. His work has recently attracted considerable interest from cost-conscious growers.

Root-zone warming as a means to save energy in the production of greenhouse crops in Australia. G.I. Moss. *Acta Horticulturae*, 1983, **133** (in press).

Root-zone warming of greenhouse tomatoes in nutrient film as a means of reducing heating requirements. G.I. Moss. *Journal of Horticultural Science*, 1983 **58**, 103–9.