Implementing partial rootzone drying

Introduction

The partial rootzone drying (PRD) method of irrigation, originally developed for grapevines, is now being used in a range of perennial tree crops in Australia and achieving some exciting results in citrus and pears, as well as grapes.

The technique requires that wet and dry rootzones are created simultaneously around each plant.

How does PRD work?

When part of the rootzone dries out the levels of abcissic acid (ABA, a plant growth hormone) in the plant increase. This sends a message to the plant leaves to close the stomata as a response to water stress, reducing shoot growth and evaporation from the leaf surface. However, because other roots still have access to water, the plant continues to grow and fruit development is not significantly affected. Alternating the wet and dry zones of the roots means that repeated surges of ABA are delivered to the shoots, maintaining conditions of reduced shoot growth and reduced transpiration, but with no significant effects on flowering and fruit development.

Research findings

The National Program for Sustainable Irrigation and its predecessor, the National Program for Irrigation Research and Development, have both funded research projects exploring PRD and its benefits. Following are some key findings.

- Cherries, apricots, apples, pears, valencia and navel oranges were assessed for their response to partial drying of the root system. Plant water use (stomatal conductance) was reduced by between 30% and 40% when one half of the root system remained unirrigated.
- PRD irrigation was applied to citrus and pear orchard trees. Flood-irrigated navel orange trees were converted to drip irrigation and PRD treatments applied by both flood and drip. In the flood treatment, water input was reduced by 40% but the trees experienced a degree of water stress, attributed to poor water infiltration into the soil.
- Drip irrigated trees showed no water stress symptoms, in trees irrigated on both sides or on one side only, even when water input was reduced by up to 80% compared with the fully irrigated flood treatment. Fruit quality and yield remained acceptable.
- PRD was applied to flood irrigated pears in the Goulburn Valley by watering only one side of the row. Water input was halved. Tree performance in terms of crop yield and quality was unchanged, as were measures of tree physiology such as stomatal conductance and shoot water potential. Measurement of soil water provided no evidence that the trees were accessing stored soil water.
- PRD irrigation to a commercial block of mature Valencia oranges reduced water application rates by between 42% and 50% compared with normal grower practice for the property and by between 32% and 43% compared with the district average. There was no significant effect on fruit size at harvest in 1998, although samples from the PRD trees taken approximately four months prior to the 1999 harvest were 5% smaller in diameter than fruit in the rest of block, but not significantly smaller than the fully irrigated experimental control.

- PRD of Navel oranges was compared in the field with full drip irrigation and flood irrigation. There was no yield penalty following conversion to drip irrigation when completed before the start of the irrigation season and where drip lines were placed 15-20 cm inside the outer canopy line on both sides of the tree. Full flood irrigation used 13.5 Ml/ha/year, PRD flood irrigation used 8 Ml/ha/year, drip irrigation used 4.8 Ml/ha/year and PRD drip irrigation used 2.8 Ml/ha/year. Fruit on PRD trees tended to be slightly smaller.
- A pot experiment over two years showed that cherry and apple trees responded quickly to partial drying of the root system. Stomatal conductance fell rapidly over the first few days of treatment and then showed recovery up to 10 days after the start of the experiment, which was similar to the situation in grapevine. However, recovery was incomplete and over the following three weeks conductance remained inhibited by about 40% compared with a fully irrigated control. At the end of the experiment dry sides of the treated trees were rewatered. A period of recovery followed, during which conductance of the treated plants reached that of the controls. In the first year of the experiment the apricot tree was less responsive than the apples and cherry.

Tips for implementing PRD

- Best PRD responses occur in soils with high values of readily available water (RAW). Shallow soils with low RAW can allow relatively small volumes of applied water to deplete rapidly. To some extent this can be overcome by more frequent irrigation.
- Use of PRD in soils with poor infiltration characteristics may also cause problems if sufficient water cannot be supplied through what is effectively 50% of the normal soil surface area.
- The amount and timing of irrigation applied to the 'wet' side should be sufficient to prevent the development of significant water deficits (soil moisture tension should remain higher than 50kPa).
- If soil moisture monitoring is available, the irrigated side of the plant should be switched when water extraction from the "dry" side becomes negligible. In sandy soils and under hot dry conditions this may be only a few days. In soils with a higher water retention characteristic and under less stressful conditions, the cycle time may become several weeks.
- Use of PRD should not result in significant reduction in midday leaf water potential when compared with standard irrigation practice.
- When PRD is being implemented in an existing orchard, total soil area wetted by the irrigation system (wet plus dry sides) should not vary significantly from that wetted by the original irrigation system. For example, conversion from flood to drip may wet only a small fraction of the available roots. The PRD irrigation system should aim to wet about half the roots at any one time.
- Correctly implemented PRD should not result in major effects on fruit quality. With Navel oranges, PRD using very low water application rates saw a reduction in fruit size in heavily cropped trees but this problem was not evident at higher water inputs. A reduction in water input, applied by flood or by drip, may result in a small but significant reduction in the percentage of juice and an increase in acid. There should be no effect on sugars and sugar/acid ratios may change accordingly.
- In pears, very low water inputs resulted in an increase in total soluble solids and a small reduction in fruit size, but at a higher level of water input (1.7 ML/ha) these effects were not evident.
- Response to PRD varies between species. It is still not known how some plants will respond.

In summary

Partial root zone drying is a very useful and significant step forward in improving the water use efficiency of some perennial horticultural crops. While there is some risk of water stress to the plant, with careful soil water monitoring these risks can be minimised. Satisfactory implementation in warm climates (areas with high levels of water evaporation), will require responsive watering systems and soils with high infiltration rates. Generally, it appears that PRD allows almost the same yields to be achieved as full irrigation, and that, at least with grapes, fruit quality is slightly better. The yields of fruit per megalitre of water applied are far superior.

Further information

The Program has produced three reports that provide more relevant information about PRD in horticulture. All are available on the web via the following links:

- Kriedemann, P. E. and I. Goodwin (2003). Regulated Deficit Irrigation and Partial Rootzone Drying. NPSI 4. Irrigation Insights: National Program for Sustainable Irrigation, Land and Water Australia. 102 pp. http://www.lwa.gov.au/downloads/publications_pdf/PR020382_c.pdf
- Loveys, B., P. Dry, et al. (1999). Improving the water use efficiency of horticultural crops. NPIRD Final Report CDH1. 36 pp. http://www.lwa.gov.au/downloads/PR990328.pdf
- Loveys, B. (2003). Improving the water use efficiency of horticultural crops. NPIRD Final Report CDH2. 52 pp.

Alternatively, copies of the reports and further information about the Program is available by:

- Contacting the Program Officer, phone (02) 6263 6005,
  fax (02) 6263 6099 or email joanne.caruso@lwa.gov.au
- Writing to the Program, c/o Land and Water Australia, GPO Box 2182, Canberra, ACT, 2601

The Program's website, www.npsi.gov.au, also features a Knowledge Base page which is a very useful starting point for identifying information sources and lessons learnt from research into sustainable irrigation, not just in Australia but overseas. The Knowledge Base is a free searchable on-line database.

About the Program

The National Program for Sustainable Irrigation focuses research on the development and adoption of sustainable irrigation practices in Australian agriculture. The aim is to address critical emerging environmental management issues, while generating long-term economic and social benefits that ensure irrigation has a viable future. The Program has 14 funding partners: Land & Water Australia (Managing Partner); Sunwater, Queensland; Horticulture Australia Limited; Goulburn-Murray Water, Victoria; Cotton Research and Development Corporation; Harvey Water, Western Australia; Lower Murray Water Authority, Victoria; Wimmera Mallee Water, Victoria; Ord Irrigation Cooperative, Western Australia; Australian Government Department of Agriculture, Fisheries and Forestry; Department of Natural Resources and Mines, Queensland; Department of Primary Industries and Resources South Australia; Department of Environment Water and Catchment, Western Australia; and Department of Agriculture, Western Australia.