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Partial rootzone drying in apple and in processing tomato

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Partial rootzone drying in apple and in processing tomato

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Abstract

New water saving irrigation strategies need to be explored and partial rootzone drying (PRD) is such a strategy as it involves irrigating only part of the rootzone with the complement left to dry to a pre-determined level. In other deficit irrigation (DI) methods the entire rootzone is irrigated with less water than evapotranspiration. I focussed on PRD for its effects on apple and on processing tomato.

For apple three field experiments were done, two on ‘Pacific Rose™’ in Manawatu and one on ‘Royal Gala’ in Hawke’s Bay. In all three, leaf water potential (Ψ\text{leaf}) was similar between PRD and commercially irrigated (CI) treatments and so were yield and fruit quality. However, ‘Pacific Rose™’ PRD fruit in one experiment had lower water loss in storage than did CI fruit. For ‘Royal Gala’, PRD fruit quality was improved in terms of flesh firmness and total soluble solids concentration. In all apple experiments PRD trees received only 50% of water given to CI trees. I recommend PRD as a feasible irrigation strategy for apples in New Zealand, but suggest further research for drier areas.

‘Petopride’ tomato was studied in six glasshouse experiments. Depending on the experiment, PRD irrigation was shifted to the previously-unwatered rootzone on the basis of volumetric soil water content, on a daily basis, and on intervals of 2, 4, and 6 days. Maintenance of Ψ\text{leaf}, photosynthetic rate, stomatal conductance, yield, and fruit quality in PRD depended on the extent of soil drying. Irrigation use efficiency was almost twice higher in PRD plants than in CI plants. Blossom-end rot was higher in some of the PRD treatments, but in an especially-designed experiment I found out that PRD per se could not be the cause. From an experiment involving the measurement of root water potential, I concluded that water does not move from the wet roots to dry roots during PRD. I found that the tomato fruit, which is normally a stronger sink than vegetative parts, becomes a weaker sink during water stress. I recommend PRD for processing tomato, but with a suitable irrigation frequency to avoid lowering the midday Ψ\text{leaf} to a value of less than −1.2 MPa. This necessitates field trials in various environmental conditions.
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Table 6.4 Influence of commercial irrigation (CI) and partial rootzone drying (PRD) on internal ethylene concentration (IEC), starch pattern index (SPI), flesh firmness
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**Table 6.5** Influence of commercial irrigation (CI) and partial root zone drying (PRD) on fruit quality of ‘Pacific Rose™’ apple after 10 weeks in storage at $0 \pm 1$ °C. Internal ethylene concentration (IEC), starch pattern index (SPI), flesh firmness (FF), total soluble solids concentration (TSSC), and fruit skin colour in terms of huge angle (HA°) are presented. Means within columns followed by the same letter are not significant different by LSD test at $P \leq 0.05$.

**Table 6.6** Influence of commercial irrigation (CI) and partial root zone drying (PRD) on fruit quality of ‘Pacific Rose™’ apple after 16 days in storage at $20 \pm 1$ °C. Internal ethylene concentration (IEC), starch pattern index (SPI), flesh firmness (FF), total soluble solids concentration (TSSC), and fruit skin colour in terms of huge angle (HA°) are presented. Means within columns followed by the same letter are not significant different by LSD test at $P \leq 0.05$.

**Table 7.1** Effect of irrigation treatments (ITs) on leaf water potential ($\Psi_{\text{leaf}}$, MPa), net photosynthesis rate ($A$, μmol m$^{-2}$ s$^{-1}$), transpiration rate ($E$, mmol m$^{-2}$ s$^{-1}$), and stomatal conductance ($g_s$, mol m$^{-2}$ cm s$^{-1}$) for tomato plants. Values of photosynthetic photon flux (PPF, μmol m$^{-2}$ s$^{-1}$ ± SD) are also shown. Means with same letters within columns are not significantly different using the LSD test at $P \leq 0.05$.

**Table 7.2** Effect of irrigation treatments (ITs) on total mass of fruit per plant, irrigation use efficiency (IUE$_{\text{TMMF}}$), and total vegetative mass per plant. Means with same letters within columns are not significantly different using the LSD test at $P \leq 0.05$.

**Table 7.3** Effect of irrigation treatments (ITs) on dry mass partitioning of tomato plants. Means with same letters within columns are not significantly different using the LSD test at $P \leq 0.05$.

**Table 7.4** Effect of irrigation treatments (ITs) on fruit water content (FWC), total soluble solids concentration (TSSC), and fruit colour in terms of hue angle (HA°). Different letters within columns indicate differences by the LSD test at $P \leq 0.05$.

**Table 8.1** Effect of irrigation treatments (ITs) on photosynthesis and stomatal conductance. Photosynthetic photon flux (PPF) is given for each occasion. Different letters within columns indicate significant differences by Tukey’s test at $P \leq 0.05$.

**Table 8.2** Effect of irrigation treatments (ITs) on the number of fruit (NF), total fresh mass of plant (TFMP), total fresh mass of fruit (TFMF), irrigation use efficiency (IUE$_{\text{TMMF}}$), and harvest index (HI) per plant. The treatments are described in the text. Different letters within columns indicate significant differences by Tukey’s test at $P \leq 0.05$.

**Table 8.3** Effect of irrigation treatments (ITs) on dry mass distribution per plant. The treatments are described in the text. Different letters within columns indicate significant differences by Tukey’s test at $P \leq 0.05$.

**Table 8.4** Effect of irrigation treatments (ITs) on mean fresh mass per fruit (MFMF), total dry mass of fruit per plant (TDMF), fruit water content (FWC), total soluble solids concentration (TSSC), blossom-end rot (BER), and fruit colour (in terms of hue angle (HA°)) at green stage and 14 days after harvest (DAH). The treatments are described in the text. Different letters within columns indicate significant differences by Turkey’s test at $P \leq 0.05$. 

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Table 11.3 Effect of irrigation treatments (ITs) on dry mass concentration of fruit (DMCF), total soluble solids concentration (TSSC), and fruit colour in terms of hue angle (HA°) at two harvest dates. The treatments are described in the text. Different letters within columns indicate significant differences by Tukey’s test at $P \leq 0.05$.

Table 12.1 Effect of irrigation treatments (ITs) on total fresh mass of plant (TFMP), number of fruit per plant (NF), total fresh mass of fruit (TFMF), total dry mass of fruit (TDMF), irrigation use efficiency in terms of TFMF (IUE_{TFMF}) and TDMF (IUE_{TDMF}), and harvest index (HI) per plant. The treatments are described in the text. Different letters within columns indicate significant differences by Tukey’s test at $P \leq 0.05$.

Table 12.2 Effect of irrigation treatments (ITs) on mean fresh mass per fruit (MFMF), dry mass concentration of fruit (DMCF), fruit water content (FWC), total soluble solids concentration (TSSC), blossom-end rot (BER), and fruit colour in terms of hue angle (HA°) at green and firm red stages. The treatments are described in the text. Different letters within columns indicate significant differences by Tukey’s test at $P \leq 0.05$.

Table 12.3 Mahalanobis squared distance and significance ($P \leq 0.0001$, ****) from irrigation treatments to irrigation treatments (ITs).

Table 12.4 Standardised canonical coefficients (SCC) and correlation coefficients (r) for the first canonical discriminant function (CDF) and thirteen horticultural attributes of ‘Petopride’ processing tomato.
List of Symbols and Abbreviations

A Photosynthetic rate
ABA Abscisic acid
BER Blossom-end rot
°C Degree Celsius
ca Approximately
Ca²⁺ Calcium
CANDISC Canonical discrimination analysis
CDF Canonical discriminant function
CI Commercially irrigated
DAA Days after anthesis
DAS Days after seeding
DAH Days after harvest
DAFB Days after full bloom
DI Deficit irrigation
DMCF Dry mass concentration of fruit
E Transpiration rate
FC Field capacity
FD Fruit diameter
Fden Fruit density
FF Flesh firmness
FI Fully irrigated
FSG Final shoot growth
FV Fruit volume
FWC Fruit water content
FWL Fruit water loss
g Gram (s)
GLM General linear model
gs Stomatal conductance
HA° Hue angle
IEC Internal ethylene concentration
ITs Irrigation treatments
IUE Irrigation use efficiency
IUE_{(TFMF)} Irrigation use efficiency on the basis of total fresh mass of fruit
IUE_{(TDMF)} Irrigation use efficiency on the basis of total dry mass of fruit
HI Harvest index
Hr Hour (s)
kg Kilogram (s)
L Litre
LSD Least significant difference
μL Microlitre (s)
μmol Micromole (s)
m Metre (s)
mb Millibar (s)
<table>
<thead>
<tr>
<th>Symbol</th>
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<tbody>
<tr>
<td>m³</td>
<td>Cubic metre (s)</td>
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<tr>
<td>min</td>
<td>Minute</td>
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<tr>
<td>Mg²⁺</td>
<td>Magnesium</td>
</tr>
<tr>
<td>Mg</td>
<td>Milligram (s)</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetre (s)</td>
</tr>
<tr>
<td>MFMF</td>
<td>Mean fresh mass per fruit</td>
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<tr>
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<td>Minimum significant difference</td>
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<td>P_i</td>
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<tr>
<td>PPF</td>
<td>Photosynthetic photon flux</td>
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<tr>
<td>PRD</td>
<td>Partial rootzone drying</td>
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<td>Root system</td>
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<td>SAS</td>
<td>Statistical Analysis System</td>
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<tr>
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<td>Standardised canonical coefficients</td>
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<td>Shoot cross-sectional area</td>
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<td>Standard deviation</td>
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<td>Standard error mean</td>
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<td>Soil-plant-atmosphere-continuum</td>
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