I. Best management practice and benchmarking

What is best management practice and benchmarking?

Best management practices are the best strategies which are currently available based on current technology and information. These practices may change as new information becomes available. The idea of best management practice in orchards is not new with a number of different titles being attributed to the integration of farm practices such as integrated fruit production. In order to develop BMPs, the processes and outcomes of a production system must be measured. These are the benchmarks. These benchmarks can then be compared with other businesses and methods developed to improve performance and achieve best management practice.

Regulation versus voluntary adoption

In Australia, the development of BMPs has generally followed the path of voluntary adoption by growers. In other parts of the world the path followed has been one of regulation. This is particularly so in Western Europe with the adoption of integrated fruit production (IFP) systems which rely on a set of guidelines involving the measurement and checking of parameters (Dickler and Schafermeyer 1993, Sansavini 1997). IFP is a regulated system involving monitoring (benchmarking) and the adoption of best management practice.

Productivity versus sustainability

Industry has traditionally undertaken benchmarking with the aim to improve productivity and returns. It is assumed that achieving better than the current situation is a reasonable outcome. However, with issues related to sustainability, best management practice develops a slightly different meaning. No longer are we only benchmarking productivity but sustainable resource use and long term environmental impacts must be considered. Sustainable use of resources incorporates the economic viability and the maintenance or enhancement of the resource base and ecosystems which are influenced by land and water resource management activities (Rendell MG uckian 1996). This philosophy is very similar to the basis of IFP where the guidelines aim to achieve an 'economical production of high quality fruit, giving priority to ecologically safer methods, minimising the undesirable side-effects and use of agrochemicals, (and) to enhance the safeguards to the environment and human health' (Dickler and Schafermeyer 1993).

Benchmarking and notional targets

When benchmarking sustainability parameters, the concept of notional targets has been developed (McG uckian 1996). These targets define the level of performance at which the farm is sustainable. These targets may differ from the performance which is achieved by the 'best' growers which will generally be considered the benchmark in the competitive production based analysis. It is vital that the benchmarks (or performance indicators) identified can be readily measured by the farmer. The notional target would generally be established externally (e.g. State and Federal Agencies) and as information is gathered the target may change. Best management practice for sustainability therefore aims to incorporate continuous improvement whereby adoption of practice moves management closer to the notional target.

Best management practice and benchmarking for irrigation, salinity and nutrients

The adoption of best management practice is vital for the stone and pome fruit industries to remain viable in the longer term. There has been considerable emphasis on adoption of integrated pest management and other factors but minimal consideration for efficient use of irrigation—scheduling, drainage, salinity and nutrient management. This paper briefly describes the issues in relation to adoption of BMPs for irrigation and outlines current projects addressing the development and adoption of BMPs for pome and stone fruit. Best management practice with respect to irrigation relies on the efficient management and integration of many factors which are part of the growers operation. These factors which include irrigation scheduling, nutrient application, leaching...
for salinity control and vigour management are briefly outlined. Management of each factor impacts on the response to other practices. This interaction and complexity of processes will be discussed.

Irrigation effects on productivity and sustainability

Irrigation management relies not only on irrigation scheduling to maintain optimum moisture levels but all factors related to the management of water in an orchard.

**Productivity** – irrigation management relies on the application of the right amount of water at the right time. Irrigation scheduling aims to maintain the optimum growing conditions for the tree and avoid over irrigation (waterlogging) and under irrigation (drought). These conditions will ensure the attainment of maximum yield, fruit size and quality.

**Sustainability** – the long-term viability of the stone and pome fruit industries relies on the maintenance or improvement of the current environmental conditions.

What are the best management practices?

**Irrigation scheduling**

Irrigation scheduling has traditionally relied on experience and observation and with systems such as flood and furrow there is little control over the efficiency of water application. However, with micro-irrigation the opportunity to control water is significantly greater. The decisions of when and how much to irrigate under micro-irrigation also become more critical. Monitoring techniques which are simple and practical are vital to assist growers in the decision making process.

The main aim of irrigation scheduling is to apply water to meet the requirement of the tree. Tree water use in an orchard will vary dramatically over an irrigation season; these variations are controlled by the crop developmental stage and the weather (evaporative demand). In a mature, well established orchard the relationship between tree water use at a particular stage and the weather will be fairly constant from year to year and can be used for irrigation scheduling (Boland et al. 1993b).

A soil pit analysis of root distribution and soil texture allows the amount of readily available water (RAW) to be determined. Ken Wetherby and Denise Bewsell assess an orchard in the Goulburn Valley.

<table>
<thead>
<tr>
<th>Flowering</th>
<th>End Stage 1</th>
<th>Fruit growth stage</th>
<th>Stage 2</th>
<th>Stage 3</th>
<th>Post-harvest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal irrigation</td>
<td>0.4</td>
<td>0.6</td>
<td>0.6</td>
<td>1.0–1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Regulated deficit irrigation (RDI)</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
<td>1.0–1.2</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Figure 1. The relationship between fruit and shoot growth of stone fruit.

The irrigation requirements over a season relate closely to the developmental stage of the tree—both the canopy coverage and the fruit growth stage. The developmental pattern is vital in understanding the sensitivity to water and other stresses. For stone fruit, the most critical period is during the final short period of rapid fruit growth (typically 4–7 weeks before harvest) when the fruit makes approximately 75% of its total growth (Figure 1).

Crop factors are used to relate the amount of water used to the weather conditions through pan evaporation ($E_{pan}$). Experiments have established that crop factors change according to the developmental stage and increase as the leaf area develops. When a maximum effective leaf area index (LAI) is reached, the crop factor is fairly constant until fruit growth accelerates and the crop factor also increases (Table 1).

A combination of soil and weather based monitoring should be used to schedule irrigation with adjustment made for nutrient and salinity management. Tree water use can be estimated from crop factors/crop coefficients and pan evaporation ($E_{pan}$)/evapotranspiration ($ET_{o}$). Soil moisture monitoring is used to check the crop factors for an individual site (Goodwin 1995).

**Regulated deficit irrigation (RDI)**

Regulated deficit irrigation was developed to reduce excessive vegetative growth of stone and pome fruit (Mitchell and Chalmers 1982, Mitchell et al. 1989). RDI relies on the development of moderate water stress early in the season when fruit are growing slowly (Stage 2). RDI has been applied to winegrapes to improve wine quality (Goodwin 1995, McCarthy 1996).

**Salinity management**

Stone and pome fruit are sensitive to saline irrigation (Maas and Hoffman 1977). In areas where irrigation water is saline (greater than 600 EC or 0.6 dS/m) an additional leaching component is critical to flush salt from the soil profile and prevent

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Table 1. Suggested irrigation crop factors for stone fruit.
accumulation in the tree rootzone. While leaching is the
strategy to manage saline irrigation, on heavy soils this may
cause waterlogging problems. The effectiveness of leaching will
depend on the soil type and the presence of groundwater
pumps or tile drains. In any situation, the leaching fraction
should be no more than 10–20% of the optimum irrigation vol-
ume and be managed with respect to fertiliser application to
ensure that nutrients are not washed through the soil.

The maximum salinity concentration of irrigation water
that can be used for stone and pome fruit will depend enor-
mously on soil type, irrigation management (e.g. leaching)
and general orchard management. For this reason, the mea-
surement of soil salinity is considered the most important
indicator of tree performance and salt tolerance levels have
been established for a number of different fruit crops. The
standard used to describe the tolerance of these species is the
soil salinity level (as measured by the electrical conductivity
of a saturated soil extract - ECe) at which a decline in
yield begins.

The absence of salt tolerant rootstocks and/or varieties for
stone and pome fruit means that irrigation management is
the only method currently available for salinity control.

The complexity and interactions of irrigation manage-
ment are highlighted when the practice of RDI management
is used with saline irrigation. While RDI is used to control
vegetative vigour and/or save water, it is a non-leaching strat-
 egy (Boland et al. 1993a). When RDI is adopted in a saline
environment it is necessary to monitor accumulation of
salts in the soil and apply strategic leaching irrigations.

Water table control
Many horticultural crops are intolerant of waterlogging,
which occurs from either excessive surface irrigation or shal-
low water tables (Rowe and Beardsell 1973). Saline water
tables have particularly adverse effects on tree productivity
where the combination of waterlogging and salinity results in
rapid uptake of salts to toxic levels and badly damages or
kills trees (West 1978, Boland et al. 1996b).

Excess irrigation increases recharge to the groundwater
and the possibility of waterlogging: Shallow water tables
during the irrigation season indicate over irrigation and can
be controlled by reduced irrigation and soil moisture moni-
toring. Little can be done about shallow water tables in
winter and spring (due to rainfall), except to ensure adequate
surface drainage and the provision of hilling in the tree row.
Groundwater pumps and tile drains will protect orchards
from shallow water tables.

Nutrient management
Irrigation management is critical for maximum uptake of fer-
tiliser by fruit trees. Fertiliser application must ensure that
nutrients are applied where and when the roots can use them.
Many nitrogen fertilisers are extremely soluble (e.g. urea)
and will leach past the rootzone very quickly. Irrigation prac-
tice and the timing of fertiliser addition during an irrigation
are therefore critical factors in positioning nutrients high in
the rootzone (Jerie et al. 1996). A piling larger doses to
compensate for losses is not the solution as inefficient fertiliser
use can also acidify soil and in the long term pollute drainage
water (McNab et al. 1995). In saline regions irrigations that
coincide with fertiliser application should not incorporate a
leaching fraction. Improved practices for nutrient management
include the application of less nitrogen with more efficient irri-
gation practices and timing nitrogen to target tree needs in a
way that minimises residual nitrogen over the winter leach-
ing period (Jerie et al. 1996).

Monitoring— the key to adoption of benchmarking and
BMPs
Stone and pome fruit production will rely more and more on
the measurement of parameters to establish the effect of par-
ticular management practices. Growers will use these mea-
surements to maximise returns and ensure minimal environ-
mental impact. Monitoring will also be included as a regula-
tory safe guard with market forces requiring demonstration of
safe and responsible practices. Monitoring needs to be simple,
practical and assess the correct parameters. Monitoring is
the key component in the constant development of best man-
agement practice. Comparison against benchmarks or notional
targets can only be achieved by monitoring specific parameters.
The measured performance can then be com-
pared with the local or overseas industry, the previous on-farm
performance or the notional target for sustainability. M onitoring is also critical to demonstrate and guarantee
responsible production practices to the consumer and gener-
al community.

Some of the key factors to monitor for development of
irrigation BMPs will be briefly outlined. A more detailed
analysis of a few simple alternative monitoring techniques
are also presented.

Irrigation scheduling
• Soil pit analysis and calculation of available water – read-
ily available and deficit available
• Soil moisture monitoring – tensiometers, gypsum blocks,
neutron probe and capacitance probes
• Weather assessment – evaporimeter (Epan) or evapotran-
spiration (ETa) and crop factors/crop coefficients.

Water table
• Test well depth
• Test well salinity

Plant nutrient and soil pH
• Leaf analysis for N and other major nutrients
• Soil pH

Salinity
• Irrigation water EC
• Soil electrical conductivity (EC1.5) and conversion to
ECe
• Leaf sodium (Na) and Chloride (Cl)
• Soil water analysis (further described below)
• Salt accumulation in trees (further described below)

![Sample EC (dS/M)](https://via.placeholder.com/150)

<table>
<thead>
<tr>
<th>Date</th>
<th>EC (dS/M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-Nov</td>
<td>0</td>
</tr>
<tr>
<td>20-Nov</td>
<td>1</td>
</tr>
<tr>
<td>27-Nov</td>
<td>2</td>
</tr>
<tr>
<td>4-Dec</td>
<td>3</td>
</tr>
<tr>
<td>11-Dec</td>
<td>4</td>
</tr>
<tr>
<td>18-Dec</td>
<td>0</td>
</tr>
<tr>
<td>25-Dec</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 2. Examples of changes in water salinity taken from two
individual soil water samples.
Soil water analysis
Ceramic soil water samplers offer an alternative to soil sampling for salinity and nutrients. The samplers consist of a ceramic tip buried in the soil and connected to a syringe via a microtube. The syringe applies a suction and collects water which can then be analysed. These samplers have been used to monitor nutrient leaching in the Swan Hill, Sunraysia and Shepparton areas (Dale pers. comm., McNab et al. 1994, Welsh et al. 1994).

Experiments were conducted to determine the viability and reliability of using soil water samplers to monitor soil salinity and develop a standard procedure for the technique (Martin and Boland 1997). A high variability in results means that at least 4 samplers per site would be required to be confident of absolute values. However, individual soil water samplers can be used to detect trends in the salinity of the soil (Figure 2). Line A represents a low salinity treatment and line B a high salinity treatment. This information can be used to warn of a salt build up or to gauge the effectiveness of leaching.

Salt accumulation in trees
The response of trees to salinity is generally based on short term information, however, as fruit trees are perennial crops they have the ability to take up salt and store it in their trunk. Growers have observed that trees show no symptoms of salt burn but then in one season will demonstrate significant damage although management and/or salinity conditions have not changed. This probably occurs because the salt store in the trunk reaches its limit and overflows. Salts then move through the tree and cause significant damage and loss in production.

A simple method to assess the amount of salts stored in the wood may assist in determining when the tree is likely to fill its storage and show salt decline. A monitoring system was investigated where 5 mm diameter cores were taken from the trunks of fruit trees exposed to different salinity levels (Boland et al. 1996a). Two adjacent pear trees in an orchard showing a number of isolated cases of salt damage were sampled. One tree demonstrated only a trace of leaf injury on one branch (normal tree) while an adjacent tree demonstrated severe injury over most of the leaves (damaged tree). There was a large difference in wood sodium (Na⁺) level between the normal and damaged trees with levels similar at the centre of the trunk but diverging in the outer increments (Figure 3). The damaged tree demonstrated a rapid increase to 145 mmol Na⁺/kg dry weight (DW) at the edge of the trunk which corresponded with severe injury to the tree. This contrasted with 20 mmol Na⁺/kg DW for the normal tree.

There appeared to be a relationship between trunk Na and salt damage symptoms. This technique requires further investigation, although it may be a useful tool to assess potential salinity damage.

Example of practical benchmarking and the development of best management practices
The following example demonstrates the grower benchmarks (developed from current best industry practice) and notional targets which may be used in the development of best management practice for irrigation. The example considers a fresh stone fruit orchard in the Swan Hill district and addresses four issue areas. The list is by no means exhaustive. Rather it attempts to illustrate the factors which need to be considered and how these factors interact.

II. Implementation of benchmarking and best management practice

Development of benchmarks and BMPs for irrigation of stone and pome fruit

A project funded by the Murray-Darling Basin Commission has been conducted over the past six months. This project aims to develop practical benchmarks through which farmers can monitor critical sustainability and productivity factors. These benchmarks will be essential tools in implementing BMPs in stone and pome fruits.

Practical benchmarks specifically suited to grower participation in monitoring will be established for orchard production and environmental management. The benchmark areas can be separated into (i) production and general orchard management and (ii) irrigation efficiency—irrigation, nutrient, salinity and water table management and regulated deficit irrigation (RDI).

<table>
<thead>
<tr>
<th>Issue</th>
<th>Parameter</th>
<th>Grower benchmark</th>
<th>Notional target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>Yield</td>
<td>Total – 30 t/ha</td>
<td>Total – 45 t/ha</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td></td>
<td>No waste</td>
</tr>
<tr>
<td>Irrigation</td>
<td>Water applied</td>
<td>Total – &lt; 9.0 Ml/ha</td>
<td>Total – &lt; 6.5 Ml/ha</td>
</tr>
<tr>
<td></td>
<td>Tensiometers Monitoring Values</td>
<td></td>
<td>Daily</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5-30 kPa</td>
<td>No drainage</td>
</tr>
<tr>
<td></td>
<td>RDI Water table</td>
<td>Test well – &lt; 2m</td>
<td>Applied when appropriate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No drainage</td>
</tr>
<tr>
<td>Salinity</td>
<td>Soil salinity</td>
<td>ECₑ &lt; 2dS/m</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Leaf Na and Cl</td>
<td>Leaf Cl &lt; 1.0%</td>
<td></td>
</tr>
<tr>
<td>Nutrients</td>
<td>Timing of N application</td>
<td>N applied in last hour of irrigation cycle</td>
<td>No leaching (nitrate below rootzone &lt; 20 ppm)</td>
</tr>
</tbody>
</table>
Grower benchmarks are being developed from a survey conducted of approximately 200 growers in four different regions (Armdale, Shepparton East, Swan Hill, Cobram). Current irrigation practice of each region will be established. Notional targets will be based on current information of water, fertiliser and salt relationships. These targets will be a particularly important component in irrigation scheduling, estimation of leaching requirements and drainage, and the management of fertiliser applications.

A monitoring program has been established and will be conducted for two years. This program will involve 40 blocks from the initial survey covering the major soil types identified and a cross-section of tree species, irrigation method and orchard management. The program has involved an assessment of soil to two metres to establish total water holding capacity and root distribution. Soil moisture, water table depth and salinity, suction tube EC and leaf nutrients will be regularly monitored. Growers will maintain records of irrigation run times, fertiliser applications, general management practices and yield and fruit size assessment. The monitoring program will be modified dependant upon grower response to the practicality of measurement methods.

A analysis of results from the two seasons of intensive monitoring and discussion through focus groups will enable practical and easy to use benchmarks to be confirmed. These benchmarks and those from other studies will be combined to develop a best management practice manual.

Large scale extension of BMPs

This project has a statewide focus with the overall aim to improve the on-farm management of soil, water and nutrient resources of horticultural industries. The component in the Murray and Goulburn Valleys is focused on issues related to best management practice for perennial horticulture. Irrigation management is critical to the management of nutrients and soil, both for production efficiency and environmental impacts. The project involves an extension program to encourage adoption of integrated on-farm BMPs and benchmarks by the wider grower community.

The development of the project has relied heavily on the program logic process (Nicholson pers. comm.). Description of the steps followed in the adoption of improved irrigation practices has enabled the identification of barriers to adoption. The project focuses on the major weak links in the sequence of steps to the final outcome of improved on-farm water efficiency. These include (i) the provision of appropriate technical information (ii) support and follow-up service and (iii) practical experience (or doing the function). The key to adoption of BMPs in the extension program is the use of demonstration and discussion via groups. These groups have been established based on existing grower groups. The use of the Farmer as Learner model (Shaw 1997) is the key to the adoption of BMPs whereby monitoring information is used by farmers to analyse their strengths and weaknesses and set goals. The farmer then makes a decision to change based on this information. This model very much follows the pattern of voluntary adoption as opposed to the regulatory approach.

Conclusion

Best management practices must integrate a multitude of factors on-farm within the physical and practical constraints of the orchard. BMPs are based on the best information and technology which is currently available and will change over time. The future of fruit production lies in the adoption of BM Ps and the key to the implementation of BMPs is the monitoring and benchmarking of parameters.

References


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