Balancing Nutrient Input and Output: CT Trial Results

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Summary

Soil solution monitoring beneath an Almond irrigation and nutrition trial identified key considerations for managing fertigation in high input/high yield almond production systems. This factsheet reports issues relating to the balance between nutrient applications, irrigation and crop requirements.

A key finding is that applied potassium can accumulate in the soil when soils are naturally high in potassium. As a result, it is important to understand the potassium requirements of the crop relative to the natural abundance of potassium in soils, before commencing a fertigation program.

The trial further illustrated a link between crop water use and nutrient uptake, identifying the need to reduce nutrient applications when irrigation volumes are limited, to avoid accumulation of ions in the rootzone, leading to elevated soil salinity.

Finally, the trial demonstrated that application of nutrients above crop requirements leads to leaching of nutrient beyond the rootzone, reducing the economic and environmental sustainability of the production system.

Areas of study which would benefit from further work were identified.

Introduction

The Almond Board of Australia, with assistance from Horticulture Australia Limited (HAL), established a trial titled “Sustainable Optimisation of Australian Almond Production” at CT Farms near Berri, South Australia. The aim of the trial was to investigate the impact of different levels of water and fertiliser inputs on Almond growth and productivity.

A number of questions were raised by the results of the trial:

• Yield increased between the low (60%) and medium (100%) irrigation treatments, but the difference was not significant.
• There were no significant yield differences between fertiliser treatments over seven growing seasons, in spite of large differences in the amount of nutrients (i.e. nitrogen and potassium) applied.
• Soil analysis indicated nitrogen and potassium were accumulating within deeper layers of the soil profile over the course of the trial.
• Leaf tissue levels of nitrogen and potassium increased over the life of the trial, and were well above levels generally seen across the Almond industry, and above the recommendations of Robinson, Treeby, and Stephenson (1997).
• Nutrient analysis of harvested fruit indicated exported nitrogen levels were 12% greater than the amount of nitrogen fertiliser applied in Treatment 1 (240 kg/ha N).
• Nutrient analysis of harvested fruit indicated exported nitrogen levels were less than the amount of nitrogen fertiliser applied in Treatment 2 (320 kg/ha N).
• Exported potassium levels were consistently lower than the amount of potassium fertiliser applied across all treatments.
• Environmental (i.e. leaching beyond the root zone) and economic (i.e. money spent on fertiliser) considerations highlighted the need to further understand the fate of applied nutrients.

All of these considerations suggested better understanding of nutrient movement and uptake were needed in order for Almond growers to make better decisions about fertiliser applications and irrigation management.

In response, the South Australian Research and Development Institute (SARDI) were invited to establish a monitoring program within the trial site, using SoluSamplers® to monitor the movement of solutes within and beyond the root zone of specific treatments (Table 1 and Table 2, and Figure 1).
Table 1: Irrigation and Nutrient Treatments

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Irrigation (% of Target)</th>
<th>Nutrient (N:K) (kg/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>100</td>
<td>240.400</td>
</tr>
<tr>
<td>T2</td>
<td>100</td>
<td>320.600</td>
</tr>
<tr>
<td>T3</td>
<td>100</td>
<td>480.800</td>
</tr>
<tr>
<td>T6</td>
<td>60</td>
<td>320.600</td>
</tr>
<tr>
<td>T7a (2001/02 to 2007/08)</td>
<td>Irregular</td>
<td>180.87</td>
</tr>
<tr>
<td>T7 (from 2008/09)</td>
<td>100</td>
<td>240.400</td>
</tr>
</tbody>
</table>

Table 2: Nutrient Treatment Details

<table>
<thead>
<tr>
<th>Nutrient Application</th>
<th>Timing</th>
<th>Target N : K Application (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>T1 &amp; T7*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Postharvest</td>
<td>21/4/09 – 15/5/09</td>
<td>75</td>
</tr>
<tr>
<td>Profile Establishment</td>
<td>5/8/09 – 12/8/09</td>
<td>32.5</td>
</tr>
<tr>
<td>Growing Season</td>
<td>1/9/09 – 6/11/09</td>
<td>132.5</td>
</tr>
<tr>
<td></td>
<td>7/11/09 – 8/11/10</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>9/1/10 – 19/1/10</td>
<td>-</td>
</tr>
<tr>
<td>Sub Total</td>
<td></td>
<td>132.5</td>
</tr>
<tr>
<td>Annual Total</td>
<td></td>
<td>240</td>
</tr>
</tbody>
</table>

* From 2008/09, T7 was modified from irregular watering and 180:87 to consider more current best practice, i.e. Treatment 1 (100% ETc, 240-400). Application dates do not always correspond; see Figure 1 for actual timing.

Figure 1: Monthly nutrient applications (kg/ha) by treatment
SoluSamplers® were installed at depths of 30 and 60 cm within the active root zone, and at 90 and 150 cm beyond the rootzone (Figure 2), and sampled weekly throughout the season. Samples were unable to be taken when soil water content fell too low (i.e. <60kPa), as happened during the dry winter of 2009.

Concentration of specific ions were analysed in the samples collected, and used to evaluate a number of hypotheses regarding the movement and fate of nutrients at the trial site.

This Factsheet discusses the results of soil solution analysis as they relate to issues of nutrient balance at the trial site.

All About Almonds - Timing Nutrient Inputs for Best Effect: CT Trial Results discusses soil solution results as they relate to the timing of nutrient applications.

Hypothesis 1

If soils naturally high in potassium receive additional potassium from fertilisers, then potassium will accumulate within the soil profile.
Hypothesis 2

If fertiliser is applied to an almond orchard receiving irrigation volumes less than the plant requirement (i.e. Treatment 6), then ion concentrations and soil salinity will increase, and reduce plant water and nutrient uptake.

Findings and Lessons Learnt

The electrical conductivity (EC) of soil solution at 30 cm depth in T2 and T6 during profile establishment and spring/summer fertigation is shown in Figure 4. The increase in electrical conductivity corresponded to decreasing water applications, with T6 considerably higher in electrical conductivity, particularly from the beginning of October.

Treatments 2 and 6 received equal quantities of fertiliser throughout the trial and the same quantity of water during profile establishment; the only difference was T6 received 40% less water from approximately September onwards.

The increase in T6 EC from October was likely a result of crop water requirements exceeding water applications, leading to lower soil water content, resulting in concentration of nutrients (i.e. salts).

The threshold value for soil saturation extract salinity (ECse) in almonds is 1.5 dS/m (Ayers and Westcot, 1989), after which yield declines. Data published by Biswas et al (2007) indicates this equates to a soil solution salinity of approximately 3.0 dS/m.

Figure 4 indicates T2 EC increased to 5.1 dS/m in late December, but was below 3.0 dS/m for most of the season. In contrast, T6 was above 3.0 dS/m from October until April (not all data is shown), and recorded a peak reading of 33.9 dS/m in early January, ten times the threshold value.

T2 and T6 nitrate concentration at 30 cm depth during profile establishment and spring/summer fertigation is displayed in Figure 5. The data indicate nitrate concentrations were generally similar throughout both periods, despite 40% less water in T6 from September. Both T2 and T6 recorded peak nitrate concentrations from mid November to mid December.

The trend of increasing nitrate concentrations from early November is similar to the electrical conductivity readings (Figure 4) for both treatments, but the consistently higher EC readings of T6 in relation to T2 was less evident in the nitrate data. This rise in concentration corresponds to a change in the applied nitrogen from Ammonium Nitrate to Urea, and also a drop in pH, but pH in T6 remains higher than in T2. It is possible that this difference in pH leads to greater volatilisation of the Ammonia derived from the breakdown of Urea, and therefore less production of Nitrate in T6 than in T2, resulting in similar concentration of Nitrate given the different volumes of soil water.

The data in Figure 6 indicates the potassium concentration at 30 cm depth was higher in T6 relative to T2 from mid September to January.

This data is consistent with the electrical conductivity readings (Figure 4), and further suggests the higher readings in T6 from mid September were likely a result of crop water requirements exceeding water applications, leading to lower soil water content, leading to concentration of nutrients (i.e. salts).

Further Work

Electrical conductivity, potassium and to a lesser degree nitrate, show increases in concentrations of ions which correspond to lower water applications. Although it is difficult to correlate this data with the quantity of nutrient uptake by the plant, the data would suggest the osmotic potential of the 30cm soil depth would be high and the conditions more difficult for water and nutrient uptake.
Further investigation of this question could lead to a better understanding of the interactions between the soil, water, nutrients and plant, and a management system that: manages fertigation via concentration; is adaptable to lower water use orchards or regions; is adaptable to recycled water sources; and is responsive to seasonal yield variations and not just area based (i.e. kg/ha) calculations.

**Hypothesis 3**

If applications of fertiliser are applied above crop requirements, then fertiliser will accumulate within the soil profile and reduce economic and environmental sustainability.

**Findings and Lessons Learnt**

Figure 7 details Almond fruit development, and Figure 8 and Figure 9 illustrate nitrate and potassium concentrations in relation to almond fruit development.

The data indicates both nitrate and potassium concentrations are relatively stable from the end of fruit/pericarp growth (i.e. early October) to hull split (i.e. early January), after which concentrations increase at all depths until mid February.

The increase in nitrate and potassium concentration from mid December within T3 corresponds to extended fertiliser applications. T2 and T3 received the same quantity of fertiliser until the end of December, after which T2 applications ceased and T3 fertiliser applications continued until mid February. It is apparent that crop nutrient demand is greatest prior to the completion of kernel (embryo) growth and declines considerably following hull split.

It is therefore evident fertiliser applications following kernel (embryo) growth, and in particular following hull split, result in an accumulation of nutrients throughout the soil which does not achieve a return on investment, and has the potential to leach and cause off-site environmental impacts. It is clear both these outcomes reduce the sustainability of almond production.

**Further Work**

Further research into the nutritional requirements of Almonds at different growth stages and monitoring of soil solution will obtain optimum return on investment with minimal impact on the environment.

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**Figure 7: Almond fruit development (adapted from Hawker & Buttrose, 1980)**

**Figure 8: Nitrate concentration in treatment 3 (480:800) associated with spring and summer fertigation**

**Figure 9: Potassium concentration in treatment 3 (480:800) associated with spring and summer fertigation**
References


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